ASSESSING THE TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE PROFICIENCY OF PRESERVICE SCIENCE TEACHERS

by

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I would firstly like to dedicate this research study to my grandmother. She passed away suddenly during this research study and her motivation to do well and achieve the impossible is greatly missed.

I would also like to dedicate this research to my family. It would not have been possible to finish this research study if it was not for their support, love, guidance and assistance.

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ABSTRACT

The purpose of this study was to investigate preservice science teachers' proficiency levels regarding their practical knowledge of technological pedagogical content knowledge (TPACK-P). An explanatory sequential mixed-method design was followed in this study and 103 participants from the University of Johannesburg formed the sample. This study commenced by identifying the different proficiency levels of the preservice science teachers using a 17-item questionnaire developed by Yeh, Lin, Hsu, Wu and Hwang (2015). Rasch's analysis was employed to analyse the data. The mean score and standard deviation for the frequency with which the preservice science teachers select an option corresponding to a proficiency level was calculated. Reliability (internal consistency) for the instrument was established. After calculating the proficiency level of the preservice science teachers, five preservice science teachers were purposefully selected for interviews in order to probe deeper into their understanding of the instructional scenarios that were provided to them in the questionnaire. The findings of the study showed that preservice science teachers have a proficiency level of 3 for their knowledge on TPACK-P. An indication was gained of infusive application where preservice science teachers use Information and Communication Technologies to guide, self-explore and independently construct their science knowledge.

Keywords: Preservice science teachers, technology integration, Rasch analysis, TPACK-P, mixed-method design

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LIST OF ACRONYMS AND ABBREVIATIONS

CK	Content knowledge
CTT	Classical Test Theories
DBE	Department of Basic Education
GDE	Gauteng Department of Education
ICC	Item characteristics curve
ICT	Information and Communication Technology
IRT	Item response theory
MLE	Maximum likelihood estimate
PCK	Pedagogical Content Knowledge
PCM	Partial-Credit Model
PK	Pedagogical knowledge
STATKON	University of Johannesburg's Statistical Consultation Service
TCK	Technological content knowledge
TK	Technology knowledge
TPACK-P	Technological pedagogical content knowledge – practical
TPCK	Technological pedagogical content knowledge
TPK	Technological pedagogical knowledge
WLE	Weighted likelihood ability estimates

CHAPTER 1
INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

Advances in information and communication technology (ICT) have diversified teacher instruction and it is claimed that "ICTs have the potential to improve the quality of education and training" (Department of Basic Education, 2004, p. 8). This is imperative for the integration of ICT in learning expressed through South Africa's White Paper 7 on e-Education (Department of Basic Education, 2004), where it is stated that "ICTs can advance higher order thinking skills such as comprehension, reasoning, problem-solving, creative thinking and enhance employability" (p. 14). ICT includes "hardware such as cell phones, computers, video cameras and the internet, and software like Microsoft Excel, Microsoft PowerPoint, Google, and simulation software for experiments" (Stott 2010, p. 147).

The Department of Basic Education's White Paper on e-Learning set a target of "all South African learners in the general and further education and training bands (GET and FET) being ICT-capable by 2013." (Stott 2010, p 147). The quality of education can be improved by having the necessary ICTs but there are issues of access to ICT in different schools, mainly schools situated in the rural areas. In South Africa's White Paper 7 on e-Education (Department of Basic Education, 2004), it is stated that "schools in Gauteng, Northern Cape, and Western Cape have, on average, a better ICT infrastructure than schools in Eastern Cape and Limpopo" (p. 13). Due to this limitation of access to ICT and the necessary infrastructure, "there is a gap in the abilities of learners and teachers to use these technologies effectively, to access high quality and diverse content, to create content of their own, and to communicate, collaborate and integrate ICT's into teaching and learning" (Department of Basic Education, 2004, p. 13). The study therefore focuses on the technological pedagogical content knowledge – practical (TPACK-P) of preservice science teachers.

1.2 BACKGROUND TO THE STUDY

Over the years, teachers have adapted their teaching methods in the classroom to introduce new concepts and content to learners, whether it was with the use of blackboards or the textbooks. Before technology was even a concept to use in the classroom, teachers were reliant on the use of blackboards and physical models to explain content to learners. With the rapid development in technology, teachers started to make use of technology as a resource to make content less abstract and more visual to learners. Teachers found that employing technology to explain and support learners' visualising of a concept had a significant influence on the learners' understanding of the concept. Jorde (2007) stated in Stott (2010) that "good science teaching has the following purposes or outcomes: effective learning of content, an understanding of a scientific approach to inquiry and an awareness of science as a social process" (p. 148). Considering these purposes for good science teaching, Stott (2010) explains that the use of "different teaching strategies and different ICT can help you achieve it" (p. 148). Shulman (1986) stated "powerful analogies, illustrations, examples, explanations, and demonstrations" can be used as various forms of representations and techniques to teach content (p. 9). The use of these techniques depends on the pedagogical content knowledge of a teacher.

Considering the different teaching methods used to teach content, Shulman (1986) defined the concept of pedagogical content knowledge, better known as PCK, as knowledge that goes beyond the teacher's knowledge of the subject matter and determining the method how this subject matter must be taught within the classroom. Mishra and Koehler (2006), with reference to Shulman (1986), described that the fundamental part of PCK is the transformation of subject matter in such a way that it makes content more understandable to learners. PCK can also be explained as the knowledge that a teacher gains over an extended period. As teachers' knowledge advances and they gain more experience in teaching certain topics, using different methods of teaching, their PCK becomes more developed and their teaching more advanced.

The appropriateness of the pedagogical representation selections and planned learning activity designs involving ICTs are determined by teachers' technological pedagogical content knowledge (TPACK). TPACK, like pedagogical content knowledge is a craft knowledge that can be defined as the wisdom that teachers develop from their teaching practices, which guides their instructional actions (Van Driel, Verloop, & de Vos, 1998). TPACK is defined by Koehler, Mishra and Cain (2013) as the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technology as a method of teaching. It is important for teachers to have the necessary TPACK to ensure the effective integration of ICT in the classroom. In addition to this, Jen, Yeh, Hsu, Wu and Chen (2016) explains that the TPACK of teachers will allow teaching of topics to be more comprehensible to the learners.

Mishra and Koehler (2006) conceptualised TPACK using Shulman as a basis, where they added “technology to the two knowledge bases of pedagogy and content, to explain technology-supported teaching and learning” (p. 46). Their framework on TPACK puts more emphasis on the “connections, interactions, affordances, and constraints between and among content, pedagogy and technology” (p. 1025). These knowledge bases of teachers cannot be isolated and will always be intertwined with one another to ensure that effective teaching will take place. As seen in Figure 1. below, Mishra and Koehler (2006) developed a model that emphasises the “complex interplay of these three bodies of knowledge” (p. 1025).

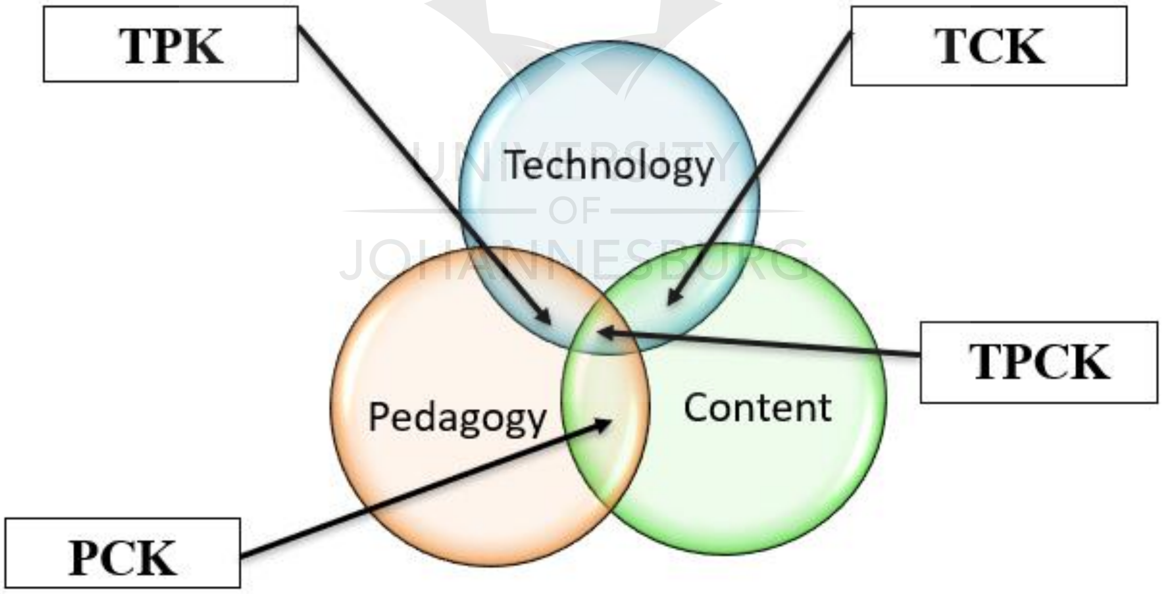

Figure 1.1: Technological pedagogical and content knowledge framework.

(Adapted from Mishra and Koehler 2006)

The above framework demonstrates the working of TPCK when it was originally developed. The framework for technological pedagogical content knowledge is now known as TPACK. As seen in the above framework, teachers must ensure that they have a good knowledge or understanding of how to use technology as a foundation for teaching content in the classroom, whether it is with the use of PowerPoint or even the use of animations and videos. The above framework also demonstrates the vast amount of knowledge teachers must have to ensure that they will have a well-developed TPACK. Taking the TPACK framework apart, we have different knowledge frameworks that relate to one another. With technological content knowledge (TCK), the teacher must be knowledgeable when it comes to using technology, for example, how to use a computer. Koehler et al. (2013) defined TCK as "an understanding of the manner in which technology and content influence and constrain one another" (p. 16). The content the teacher wants to teach can be enhanced by technology itself. The teacher must be able to understand how they can use technology to teach various concepts in their classroom.

The framework also includes technological pedagogical knowledge (TPK) as a knowledge framework. Technological pedagogical knowledge is defined as "an understanding of how teaching and learning can change when particular technologies are used in particular ways" (Koehler *et al*., 2013, p. 16). In this knowledge framework, the teachers consider the various techniques that could be used to teach that content. Smartboards or virtual software can be used to explain the content. A teacher can also decide to use the computer to display PowerPoint presentations with the content and include pictures, or the laptop can be used to view videos and animations on concepts that learners might find difficult. The TPACK framework also allows for the utilisation of better teaching techniques, that allows teachers to implement technology-assisted teaching effectively allowing for a deeper approach to the content. Jen, Yeh, Hsu, Wu and Chen (2016) explained that teachers in our "digital age" should ensure that they know how to use technology properly in their classrooms (p. 46).

With TPACK as a framework for technology-assisted teaching, the model for TPACK-Practical (TPACK-P) was developed. Yeh et al., (2015) explained that TPACK-P refers to a knowledge framework that is developed by science teachers for their practical teaching with ICTs as an assistance. Ay, Karadag and Acat (2015) explained TPACK-P as the knowledge that is developed by teachers using their experiences in long-term planning and instruction of using ICT to support their different teaching needs.

Therefore, TPACK-P is a teacher's knowledge of technology and decisions on how this can be practically applied within the science classroom.

The technologies that were used in the classroom before the implementation of the internet, educational games and virtual software, included the blackboard, models and even pictures found in magazines and books. In the modern era, the form of technology that is used by teachers to assist the teaching of concepts are laptops, educational videos, virtual software that demonstrate a laboratory, and the internet that represents the necessary content needed to teach learners (Mishra & Koehler, 2006). The South African White Paper 7 on e-Education states "e-Education will connect learners and teachers to better information, ideas and to one another via effective combinations of pedagogy and technology in support of educational reform" (p. 14). By having this resource at hand, teachers will have access to the needed information to allow them to explain content in a more comprehensible way but also demonstrate it to learners.

The Gauteng Department of Education has officially launched the roll-out of technology enabled teaching and learning programmes to teachers and grade 12 learners. The programme known as "The paperless classroom" entails the usage of interactive whiteboards and mobile devices such as tablets and laptops, with complete internet connectivity to conduct teaching and learning.

The roll-out of the technology in our South African classrooms can have a positive impact on the education of our learners but there are also a few barriers to this technology-assisted teaching. Teachers are not all trained in the effective implementation and the use of technology in their classrooms. Jen, Yeh. Hsu, Wu and Chen (2016) explain that the "lack of necessary knowledge and confidence" contributes to the unsuccessful usage of technology (p. 45). Mumtaz (2000) stated a list of inhibitors has been found in previous studies. A few of the barriers to the limited use, is the "lack of teaching experience with ICT, lack of on-site support for teachers using technology, lack of supervision of children when using computers, lack of ICT specialist teachers to teach students computer skills, lack of computer availability, and lack of financial support." (p. 320). Mishra and Koehler (2006) further explains that "teachers will have to do more than simply learn to use currently available tools; they will also have to learn new techniques and skills, as current technologies become obsolete" (p. 1023). Consequently, as technology becomes outdated every year, teachers should stay updated to ensure they will use technology effectively with different techniques. To ensure that teachers stay updated with all technological developments, "teachers need to be provided with adequate facilities and training to be able to use those facilities, in order to progress in technology-rich context" (Mumtaz, 2000, 336).

1.3 RATIONALE

With the use of surveys and questionnaires, researchers have tried different approaches in investigating teachers' TPACK. These surveys and questionnaires allow teachers to choose answers on these surveys and questionnaires that is more suitable to their understanding of TPACK. The resulting information has not only revealed how well teachers' knowledge and application is developed on teaching with technology, but constructive directions for future teacher education was also established. There is thus a renewed sense of urgency for teacher education institutions to adequately prepare teachers to fulfil this mandate of technology-assisted teaching.

This research provides information on the competency of student teachers in science education implementing ICT use in their classrooms and identifying specific gaps in teacher TPACK such as ICT-integrated teaching strategies, ICT to assess learners and ICT and instructional management. This baseline information could be useful for higher education institutions in reviewing their teacher development programmes for student science teachers. Yeh, Lin, Hsu, Wu and Hwang, (2014) elaborated that teacher education programs should not only focus on the integration of technology but also on the experiences of teachers using technology in the classroom.

Given the potential contribution of ICT to learning, there is a need to closely assess teacher competency in their instructional actions while integrating ICT into their teaching practice.

The research proposed in this study is on the TPACK-P proficiency of preservice science teachers.

1.4 AIMS AND OBJECTIVES

The aim of this study is to assess the TPACK-P proficiency of preservice science teachers.

The objectives of the study are as follows:

1. To determine the TPACK-P of preservice science teachers using a validated questionnaire; and
2. To probe preservice science teachers on their questionnaire responses using interviews.

1.5 RESEARCH QUESTION

The research is guided by the following research question:

What is the TPACK-P proficiency of preservice science teachers?

1.6 CONCEPTUAL FRAMEWORK

Various models of TPACK have evolved from different perspectives on the role of ICT integration (Ay, Karadag & Acat, 2015). In large part, these models address knowledge and skill dimensions independent of teaching experience.

The TPACK-P model, however, focuses on teaching experience and is a knowledge-based framework for science teachers that "considers the teaching process as the basis upon which application knowledge (teaching experience) and TPACK skills work together" (Ay, Karadag & Acat, 2015, p. 98). TPACK-P includes "eight instructional phases or dimensions that teachers would encounter and consider in their Science instruction" (Yen et al., 2015, p. 79).

Within the model of TPACK-P, there are three knowledge domains that play a key role in the teaching environment: planning and designing, practical teaching and assessment. Within these three knowledge domains, five pedagogical areas were identified as competencies teachers must develop in TPACK-P. The five pedagogical areas are learner content, subject content, curriculum design, practical teaching and assessments. The eight instructional phases or dimensions that are included in the model of TPACK-P are using ICT to understand students, using ICT to understand subject content, planning curriculum, representations, teaching strategies, instructional management and teaching practices (Yeh et al. 2014).

The planning and designing domain refer to the techniques that teachers use to prepare the curriculum adaptively with the considerations of learners' individuality and features of the target curriculum. Yeh et al., (2015) explained that planning and designing is when "teachers prepare for upcoming teaching practices" (p. 79). When teachers are planning and preparing for their lessons, they must consider the different teaching techniques they are going to use in the lesson but also the learners' knowledge of what the topic demands. When teachers understand what learners understand, but also what they struggle with, the lesson plan can be improved using various teaching techniques, including technology. With technology as a teaching technique, misconceptions that learners might have on a concept can be included in the lesson planning and teachers can retrieve different educational videos to demonstrate the concept.

The practical teaching domain involves teaching practically and employing the various techniques to ensure that ICT-integrated instruction can be carried out smoothly in various learning contexts. In Science education, teachers cannot rely on theoretical knowledge alone; practical application of the theoretical knowledge plays an important part in learners' understanding. Yeh et al. (2015) explained: "Science teaching needs to guide and support students as they explore nature and make inquiries, while ICTs offer stimuli, representations and channels" (p. 80). Concepts within science need to be practically implemented in the classroom to ensure that learners grasp the content. Even though chemicals are expensive for some schools, the use of technology can improve the practical teaching of some practical concepts. Teachers do not have to rely on the use of chemicals to demonstrate the effects to learners, technology can be used to virtually demonstrate the theoretical concepts to the learners. Yeh, Lin Hsu, Wu and Hwang (2015) explain that "ICTs offer stimuli, representations, and channels to accommodate preservice science teachers with heterogeneous cognitive development in different inquiry activities" (p. 80).

Lastly, the assessment domain involves assessing how learners are using multiple techniques to construct knowledge (Yeh, Hsu, Wu, Hwang, & Lin, 2015). The assessment domain also includes the techniques teachers use that inform them about their learners. In science education, learners develop misconceptions on concepts, and this can affect their overall understanding. Technology can be used to continuously assess the learners in a lesson on concepts that poses a problem. TPACK-P suggest that teachers' knowledge in ICT-infused assessment is critical, since it determines how well they assess students' learning with proper ICT tools and strategies (Falk 2012; Fan, Wang & Wang, 2012).

1.7 RESEARCH METHODOLOGY AND DESIGN

This research followed an explanatory sequential mixed-methods design (Creswell, 2014). This design involves a "two-phase project in which the researcher collects quantitative data in the first phase, analyses the results, and then uses the results to plan (or build onto) the second qualitative phase" (Creswell, 2014, p. 224). It is considered explanatory because the initial quantitative data results are explained with the qualitative data. It is sequential because the quantitative phase is followed by the qualitative phase.

The first phase of the research involved collecting quantitative data from a sample of 200 Life, Natural and Physical Sciences preservice science teachers. The sample was selected applying the technique of convenience sampling as the preservice science teachers are located at the same university where I am registered, and hence it is anticipated that this helped with accommodating easy access to the sample.

The quantitative data was collected by means of a questionnaire developed by Yeh et al. (2015). The questionnaire comprised 17 items that describe instructional scenarios on science teachers' implementation of ICTs in their instruction. Hence, the items solicit data on teachers' TPACK-P proficiency levels. This instrument has been administered previously to preservice teachers (Jen, Yeh, Hsu, Wu, & Chen, 2016), and is deemed appropriate for the targeted sample in this study. The items in the questionnaire have been clustered together according to the three knowledge dimensions mentioned earlier. Questions one to six focus on the assessment dimension of the preservice science teachers. Questions seven to 13 focus on the planning and designing knowledge dimension. And lastly questions 14 to 17 focus on the enactment knowledge dimension. Each item has four options that individually represent typical performances that teachers at levels 1 to 4 display. Level 4 (reflective application) is the highest proficiency level that science teachers could achieve, and it indicates that they are adept at using their experience-based TPACK to employ ICTs in assisting their learners in learning about science. Teachers at level 3 (infusive application) use ICTs to guide students to self-explore and independently construct their science knowledge, whereas teachers at level 2 (simple adoption) use ICTs to help learners learn about science but via more teacher-centred strategies or with less well-founded rationales. Level 1 represents teachers that only have a basic understanding of technology resulting from their lack of, or limited experience, negative impressions regarding technology in the classroom, or a lack of intention to implement ICTs in their classrooms. The data collected was analysed by employing Rasch analysis. The mean score and standard deviation for the frequency with which the preservice science teachers select an option corresponding to a proficiency level was calculated. Reliability (internal consistency) for the instrument was established by calculating Cronbach's alpha.

The second qualitative phase of this study involved interviewing preservice science teachers who were purposefully selected from the quantitative survey sample of the first phase. I have grouped the respondents from the quantitative phase into categories based on their TPACK-P proficiency levels, and randomly chose three representative individuals per group for qualitative data collection. Individual interviews were used to probe deeper into the answers the preservice science teachers provided on the questionnaire. The interviews were audio-recorded and transcribed. Interviewed data was coded and classified (Babbie & Mouton, 2009) through a process guided by trends and patterns, which would have emerged from the analysis of the questionnaire data in relation to integration of ICT in science teaching. Lesson plans regarding how preservice teachers integrate ICT in their lessons were also analysed to gain further insight into the TPACK-P proficiency of these teachers.

1.8 RELIABILITY AND VALIDITY

The following validity and reliability check for the qualitative data as suggested by Merriam (1998) was adhered to:

1. *Triangulation:* I used questionnaire and interview data to build a coherent justification of emerging findings.
2. *Member checks*: I checked data and tentative interpretations with the preservice teachers.
3. *Peer review*: There will be ongoing dialogue and critical reflection with other researchers on the research process and tentative interpretations. The work was also presented at a student seminar organised by the Science Education Unit at UJ.
4. *Reflexivity*: Critical self-reflection was done regarding anything that may bias my interpretation e.g. hidden assumptions, own worldview, theoretical orientation and interrelationships with the teacher.
5. *Audit trails*: I provided a detailed account of methods, procedures and reasons for decisions. I maintained a journal to document my progress.
6. *Rich description*: I provided a detailed description of events to enable readers to contextualise the study and judge the extent to which the findings could apply to their situation.

1.9 ETHICAL CLEARANCE

Ethical clearance to conduct the research was sought from the ethical clearance committee, Faculty of Education at the University of Johannesburg. The ethical clearance for the research was granted.

Consent was obtained from the preservice science teachers who participated in this study. The intent and purpose of the research was clearly communicated to the preservice teachers involved. The participants were assured of the confidentiality of their participation, and it was made clear that they could withdraw at any stage of the research.

1.10 OUTLINE OF CHAPTERS

The outline of the chapters of the research study is as follows:

Chapter 1 is the introduction to the study. This chapter will include the introduction to the study as well as a background to the study. It also introduces the research question and the conduct of the research.

Chapter 2 is the review of literature that is relevant to this study and explains the conceptual framework of TPACK-P used as a model in the study.

Chapter 3 provides a detailed account of the research design and methodology that was followed in this study.

Chapter 4 entails a detailed discussion of the data that was collected, including the interpretation of that data. A summary of the findings is also discussed.

Chapter 5 provides a discussion on the conclusion of the study including recommendations of the implementation of ICTs in the classroom through developing teachers' TPACK-P.

1.11. CONCLUSION

In this chapter a brief outline of the chapters in the study was provided. This chapter a brief overview on the chapters to follow and what each chapter will discuss.

CHAPTER 2

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 Introduction

In the previous chapter, the context and the research question that guided this study were discussed in detail. This chapter presents an in-depth review of literature on the research of TPACK-P of preservice and in-service teachers. Various readings have been published on the concept of PCK and the concepts that make up TPACK. These various readings allow in-depth reviews to take place, to allow a better understanding of the different knowledge systems that make up PCK and TPACK, with the added technological knowledge system contributing towards the development of the TPACK-P framework used in this study. The benefits and barriers on technology implementation will be discussed.

Several discussions on TPACK are provided in the literature relating to preservice teachers as well as in-service teachers. This chapter commences with the definitions and discussion on the terms of PCK, TPACK and TPACK-P in detail. I then provide detailed discussions on the barriers that are experienced by preservice teachers and in-service teachers in the implementation of technology-assisted teaching in the science classroom, including the benefits on the use of technology. Next, I outline the role of tertiary institutions in providing the necessary support to preservice teachers on the possible ways of implementing technology in the classroom. This literature view will focus on the knowledge forms of the framework of TPACK, as well as the practical application of TPACK in the classroom.

2.2 Teacher knowledge forms composing the framework of PCK

The following section will focus on the different knowledge categories of content knowledge (CK), pedagogical knowledge, that constitute the framework of pedagogical content knowledge (PCK). Considering the research aim of this study, the practical application of CK with the use of technology will be the focus of this section.

2.2.1 Content knowledge

Science teachers have various knowledge categories that allow them to teach scientific inquiry adequately to learners. Shulman (1986) explained that CK can be divided into three distinct categories: “a) Subject matter content knowledge, b) pedagogical content knowledge and c) curricular knowledge” (p. 9). The first knowledge category a teacher has is known as CK as seen in Figure 2.1 on page 16. Shulman (1986) defined CK as the “amount and organisation of knowledge per se in the mind of the teacher” (p. 9). CK as defined by Koehler, Mishra and Cain (2013) is the knowledge a teacher has about the subject matter they need to teach in the classroom. The CK of teachers in science must be well-developed to ensure abstract concepts, that are difficult for learners to grasp, will be taught in a proper manner.

Shulman (1986) explained that the knowledge of a teacher will include diverse types of theories, ideas, organisational frameworks, evidence and proof, as well as established practices and approaches regarding that subject. Shulman (1986) explained that teachers need to be able to explain “why a particular proposition is deemed warranted, why it is worth knowing and how it relates to other propositions” (p. 9). Considering this theory, teachers must be able to explain to learners why it is necessary to know and understand this theory. Making use of technology, teachers can explain this theory with the use of videos or even simulations. If Life Science is considered, several theories need to be explained by the teacher to ensure that learners will understand the content that will follow, and how it relates to scientific phenomena taking place on earth. A good example from the Curriculum and Assessment Policy Statement, Life Sciences (Department of Basic Education (DBE), 2011) is the theory of evolution by natural selection established by Charles Darwin (p. 61). This theory explains how animals must adapt to different environments to survive. This theory is understood by learners under the term of “survival of the fittest”.

If the teachers have a poor understanding of the topics in a subject, teaching of the topics will also be poor. “The cost of not having a comprehensive base of content knowledge can be prohibitive. For example, preservice science teachers can receive incorrect information and develop misconceptions about the content area” (National Research Council, 2000; Pfundt & Duit, 2000). Teachers will therefore not be able to teach proper content to the learners and misconceptions and negative perceptions towards the subject or specific content can develop. Koehler et al. (2013) explained that “knowledge and the nature of inquiry differ greatly between fields and teachers should understand fundamentals of the disciplines they teach. In the case of science, for example, this would include knowledge of scientific facts and theories, the scientific method, and evidence-based reasoning” (p. 14-15). Teachers have numerous ways to represent CK and one commonly used is the Bloom’s cognitive taxonomy that demonstrates CK on various levels but also helps them to focus on how content needs to be taught to learners on various levels (Shulman 1986). Other ways that may be used by teachers may include “Gagne’s varieties of learning, Schwan’s distinction between substantive and syntactic structures of knowledge and Peters’ notion that parallel Schwan’s” (Shulman 1986, p. 9).

2.2.2 Pedagogical knowledge

Pedagogical knowledge (PK) is the second knowledge category in the CK that teachers must possess as seen in Figure 2.1. PK can be described as the knowledge that a teacher possesses that allows them to choose the proper approach or application to teach different scientific concepts to learners. Koehler et al. (2013) defined PK as “teachers’ deep knowledge about the processes and practices or methods of teaching and learning” (p. 15). Numerous approaches are available to teachers to teach different scientific concepts to learners and allow scientific phenomena to be experienced by learners. If we consider the “digital-age teachers” (Jen et al., 2016, p. 46), the use of computers and visual simulations can be considered by teachers as a teaching method. The National Curriculum Statement or The Curriculum and Assessment Policy Statement, Life Sciences (Department of Basic Education (DBE), 2011) states that “a careful selection of scientific content and the use of a variety of methods to teach and learn science should promote the understanding of science as a human activity as well as the history of science” (p. 12). As Ferreira (2010) states “chalk and chalkboards have always been considered the basic tools of the teaching profession” (p. 125). In relation to the digital-age teacher, experienced teachers have more experience when it comes to the use of a blackboard as a suitable approach to teach science alongside practicals and dissections.

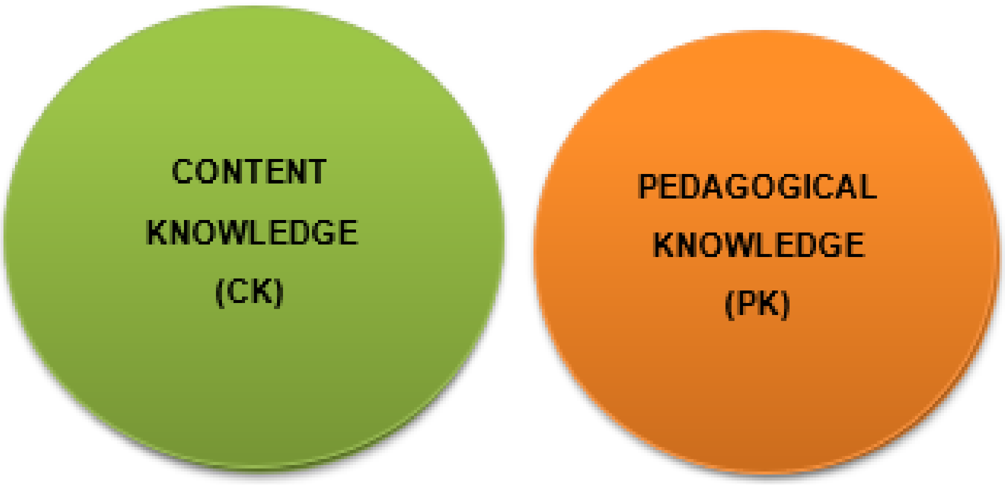

Figure 2.1: Two knowledge systems that teachers possess

(Adapted from Mishra and Koehler 2006)

2.3 Pedagogical content knowledge

Considering the two categories of content knowledge explained above, the concept of PCK was developed by Shulman (1986). Teachers can use various teaching methods to teach content to learners and therefore, PCK is defined by Shulman (1986) as the knowledge that goes beyond the teacher's knowledge of the subject matter determining the method to use on how this subject matter must be taught within the classroom. PCK also includes an understanding of what makes the learning of specific topics in the curriculum easy or difficult for learners. Mishra and Koehler (2006) with Shulman (1986) as a basis described that the fundamental part of PCK is the transformation of subject matter, in such a way that it makes content more comprehensible to learners. When teaching takes place, teachers must be able to constantly adapt their approach in the classroom to ensure maximum understanding and minimal confusion.

Considering the definition of Shulman (1986) various researchers made use of the definition but adapted it according to their own understanding. Koehler, Mishra, and Cain (2013) defined PCK as "teacher interprets the subject matter, finds multiple ways to represent it, and adapts and tailors the instructional materials to alternative conceptions and preservice science teachers' prior knowledge" (p. 15). Jen et al. (2014) explained that PCK refers to "an integrative set of knowledge not just merely composed of subject content and pedagogy but also with experience-based knowledge offering a bridge connecting knowledge of content and pedagogy" (p. 3) as seen in Figure 2.2. If we consider the above definitions of PCK, a teacher must have knowledge on various teaching methods to ensure the proper method is chosen to teach the specific content to learners. PCK as a unique body of knowledge must never be static but rather constantly change as situations in the classroom change (Cochran, DeRuiter & King, 1993).

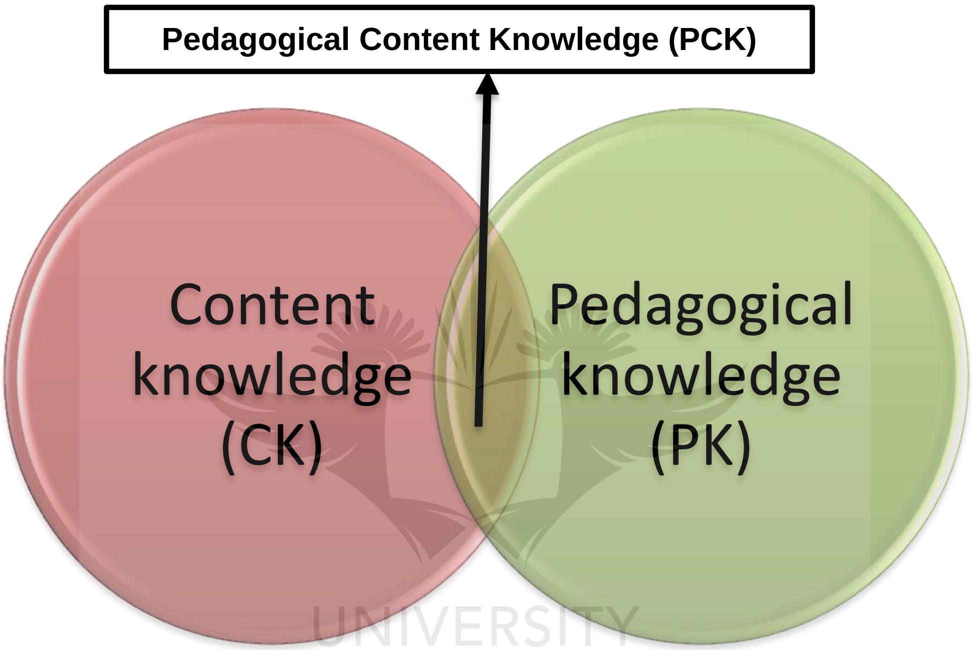

Figure 2.2: Knowledge systems of PCK

(Adapted from Mishra and Koehler 2006

A teacher's experience must be a bridge between the subject matter they teach and the approaches they use to teach. If a teacher does not have a lot of experience when it comes to the use of different approaches, learners might struggle to understand the subject matter and develop misconceptions. Shulman (1986) stated "powerful analogies, illustrations, examples, explanations, and demonstrations" (p. 9) can be used as various forms of representations and techniques to teach subject matter. The use of these techniques depends on the PCK of the teacher. If a teacher has a low PCK, using these various forms of representations will be limited and restricted. The use of chalk-and-talk will be the main teaching approach. A teacher with a moderate to a well-developed PCK will be able to adapt throughout a lesson and make use of various forms of representations to teach the subject matter in an approachable manner. “In-service teachers tend to display more integrated PCK than preservice teachers” (Lee, Brown, Luft, and Roehrig, 2007; Lee and Luft, 2008).

2.4 TPACK framework

The appropriateness of the pedagogical representation selections and planned learning activity designs involving ICTs are determined by teachers’ TPACK. TPACK, like PCK, is a craft knowledge that can be defined as the wisdom that teachers develop from their teaching practices which guide their instructional actions (Van Driel, Verloop, & de Vos, 1998). TPACK is “an extension of Shulman’s (1986, 1987) notion of pedagogical content knowledge – the specialised knowledge required to teach differently within different content areas – which revolutionised our understanding of teacher knowledge and its development” (Harris & Hofer, 2011, p. 212). TPACK is defined by Koehler, Mishra and Cain (2013) as the basis of effective teaching with technology requiring an understanding of the representation of concepts using technology as a method of teaching.

It is important for teachers to have the necessary TPACK to ensure the effective integration of ICT in the classroom. In addition to this, Jen, Yeh, Hsu, Wu and Chen (2016) explain that the TPACK of teachers will allow teaching of topics to be more comprehensible to the learners. Angeli and Valanides (2009) defined the concept of TPACK as the integrated set of knowledge demanding transformational mapping of factors and considerations of learners, pedagogy, representations and tool affordances.

Considering the various definitions of TPACK provided by various researchers, the concept of TPACK independently demonstrates the various knowledge systems that teachers must have. As discussed earlier in the chapter, the basic knowledge systems that teachers must have is CK and PK. With the concept of TPACK being developed, Mishra and Koehler (2006) included technological knowledge (TK) within the framework of PCK and developed the framework of TPCK. Mishra and Koehler (2006) included technology and developed an “indispensable knowledge set that teachers should develop” (Yeh et al. 2014, p. 3). Sheffield, Dobozy, Gibson, Mullaney and Campbell (2015) explained that the developers of the framework of TPACK have added the "A" in TPACK to "emphasize the interrelationships between the concepts" (p. 229). Koehler et al. (2013) also explained that the "TPACK framework explains how teachers' understanding of educational technologies and PCK interact with one another to produce effective teaching with technology" (p. 14). With learners becoming more technologically advanced in the modern era, teachers also need to adapt to ensure they stay updated with new technological developments. Mishra and Koehler (2006) explained that they have added technology to the framework of PCK "to address technology-supported teaching/ learning environment" (p. 46).

In the next section the concepts of TK, TCK and TPK will be discussed as part of the technology category of TPACK-P.

2.4.1 Technological knowledge

Technology is becoming more advanced, placing more pressure on teachers to adapt and make use of technology in their teaching. To enable teachers to adapt to the use of technology, they must have the necessary TK. TK is very difficult to define due to its changing nature. Technology is constantly changing and becoming more advanced, making available definitions of TK outdated almost daily. TK will therefore be more appropriately explained as knowledge that will enable teachers to "accomplish a variety of different tasks using information technology, and to develop different ways of accomplishing a given task" (Koehler et al. 2013, p. 15). Teachers can use various methods to accomplish different tasks in the classroom, but they must have sound knowledge on the use of ICTs to expand on the teaching methods available to them. Mishra et al. (2006) defined TK as the knowledge about technology such as blackboards, books, computers and even software and the use thereof. Teachers have basic knowledge on the use of textbooks and blackboards but need to develop a better understanding of the use of computers, software and even videos to demonstrate content to learners.

2.4.2 Technological content knowledge

TCK includes a knowledge system that teachers develop on the use of technology in their classroom. Koehler et al. (2013) defined TCK as "the understanding of the manner in which technology and content influence and constrain one another" (p. 16). Considering this definition, teachers must understand the subject matter that they will be teaching to the learners, but also consider what form of technology they will use, whether it is with the use of videos, simulations or slides presented on PowerPoint.

2.4.3 Technological pedagogical knowledge

PK considers the practical teaching with technology in your classroom. TPK can be defined as the “understanding of how teaching and learning can change when particular technologies are used in particular ways” (Koehler et al. 2013, p. 16). Teachers must be able to understand how the use of technology in the classroom benefits their teaching as well as benefits the learners to help them understand the subject matter being taught.

Therefore, TPACK can be explained as a craft knowledge that guides teachers’ instructional actions, with technology as a method of teaching. “Teachers’ development begins with being equipped with professional knowledge about the content to be taught, the pedagogy and assessment necessary to assist their students’ content learning, and the technology required to further accommodate that teaching and learning. These knowledge sets interact to produce a blended technological-pedagogical-content knowledge set” (Mishra & Koehler, 2006 in Jen et al., 2016, p. 46). TPACK for science teachers may include their knowledge regarding the representations of content, the science curriculum, students’ understanding of science, various educational contexts and affordances of ICT tools (Angeli & Valanides, 2009; Jimoyiamis, 2010; Magnusson, Krajcik, & Borko, 1999).

In Figure 2.3, the concepts that make up the framework of TPACK are demonstrated as well as the interrelationships that are formed between the different concepts. Each one of these types of teacher knowledge are influenced by contextual factors, such as culture, socio-economic status and school organisational structures. Thus, “TPACK, as it is applied in practice must draw from each of its interwoven aspects, making it a complex and highly situated educational construct that is not easily learnt, taught or applied “(Harris and Hofer, 2011).

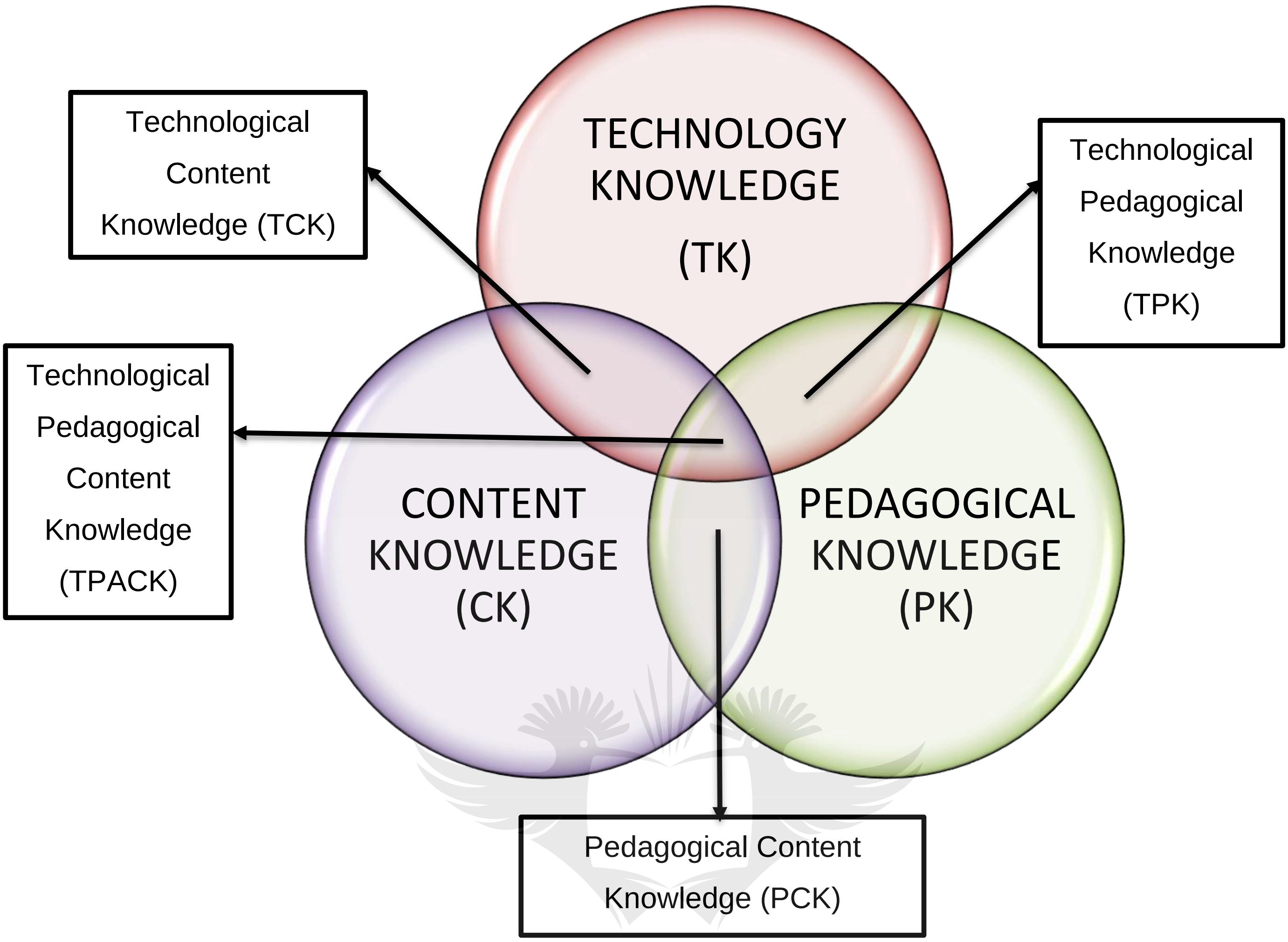

Figure 2.3: The knowledge framework of TPACK

(Adapted from Mishra and Koehler 2006)

The TPACK framework seeks to "assist the development of better techniques for discovering and describing how technology-related professional knowledge is implemented and instantiated in practice. By describing the types of knowledge teachers need, educators are in a better position to understand the variance in levels of technology integration that occurs" (Koehler, Mishra & Cain, 2013, p. 18).

2.5 TPACK-P framework

Bearing in mind Figure 2.3, preservice teachers and in-service teachers will not have the same body of knowledge. Jang and Tsai (2012) explained that various TPACK models have been proposed and a lack of a proper TPACK model still exists that takes into consideration the knowledge of teachers as well as their experience within teaching. They also stated that the amount of teaching experience a teacher has can be used as an indicator of teacher proficiency in TPACK. “Considering that both TPACK skills and personal teaching experiences compose teachers’ TPACK-P, it is expected that experienced teachers have stronger TPACK-P than novice teachers or preservice teachers” (Jen et al., 2016, p. 46).

Several teacher training models have also been proposed and validated that emphasise the development of teachers TPACK regarding certain technology (Yeh et al. 2013). With TPACK as a framework for technology-integrated teaching, the model for TPACK-P was developed. A study was done by Yeh et al (2014) using the Delphi survey technique to develop a TPACK model identifying the knowledge that makes up the teacher’s TPACK practical. The results of this study also identified a range of factors that determine teachers’ implementation of technology in the classroom, in this case science teachers.

Numerous definitions for the framework of TPACK-P have been provided by researchers taken altogether they share the concept of technology playing a role as an assistant to teaching. Yeh et al. (2015) explained that the TPACK-Practical (TPACK-P) refers to a knowledge framework that is developed for teachers for the practical teaching with ICTs and in this study the focus was specifically on science teachers. Ay, Karadag and Acat (2015) in turn defined TPACK-P as the knowledge that is developed by teachers using their experiences in long-term planning and instruction using ICT to support their different teaching needs. Therefore, TPACK-P is a teacher’s knowledge of technology and how this can be practically applied within the classroom to assist their teaching. TPACK-P can also be defined as a practical knowledge framework that science teachers will develop when they make use of ICTs in their classroom to assist their teaching (Yeh et al. 2015).

The resources that were used by teachers in the classroom before the implementation of the internet, educational games and virtual software was: blackboards, models and even pictures found in magazines and textbooks. Mishra & Koehler (2006) explained that in the traditional classrooms a variety of technologies were used that included textbooks and overhead projectors, and charts demonstrating different topics that were put up on the wall. In the digital age, the form of technology that is implemented by teachers to assist in the teaching of concepts are laptops, educational videos, software that will be able to demonstrate a virtual laboratory, and the internet that can represent the necessary content needed to teach learners (Mishra & Koehler, 2006).

The South African White Paper 7 on e-Education states “e-Education will connect learners and teachers to better information, ideas and one another via effective combinations of pedagogy and technology in support of educational reform” (p. 14). By having these resources at hand, teachers will have access to the needed information to allow them to explain content in a more comprehensible way, but also demonstrate it to learners when explanations are not effective enough. Jen et al. (2016) explained that “teaching practices are the result of the complex and convoluted interactions of instructional, social and physical factors: there are no one-size-fits-all solutions for instructional tasks” (p. 46).

Yeh et al. (2015) claimed that teachers’ proficiency in TPACK-P will develop more as they become focused on learners in their teaching, and with teaching experience, although it might take some years to be reflected in their TPACK-P proficiency. Considering the explanation provided by Yeh et al. (2015) above, as teachers start using ICT more prominently in the classroom, their development of TPACK-P will be enhanced, and the use of technology will become more effective. The development of a teacher’s TPACK-P is thus a gradual process a gradual process or learning and experiencing.

A teacher that makes use of ICT in the classroom cannot be considered to have a well-developed TPACK-P. The development of TPACK-P will be a slow process over multiple years ensuring that the teacher developed the proper uses of ICT in their classroom. As the teaching experiences of teachers with ICTs progresses and their TPACK-P proficiency improves, experience with technology will be effectively demonstrated. Jen et al. (2016) explained that preservice teachers or newly employed teachers will have a lower TPACK-P proficiency than that of teachers that have experience in the field of teaching. Preservice teachers have only practical experience of a few weeks when they go on school experience, depending on the university they attend, as opposed to experienced teachers that have many years of experience in the teaching industry as they are in the classroom busy teaching daily. Yeh et al. (2015) specified that preservice teachers will develop their TPACK-P when they observe teachers and the actual teaching practices of these teachers in the classroom. When preservice teachers observe teachers in practice, they get first-hand experience on what teaching methods work best in certain situations and what teaching methods do not.

The TPACK-P framework consists of three knowledge domains and eight knowledge constructs that will be considered in the science instruction of teachers during a science lesson. The three knowledge domains that make up the framework of TPACK-P are planning and designing, assessment and practical teaching.

The planning and designing domain mainly refer to the practices teachers will use to plan their lessons, considering the use of ICTs in the lesson, different teaching techniques, the learners' knowledge of what the topic demands. Yeh et al. (2015) defined planning and designing as teachers preparing for their "upcoming teaching practices" (p. 79). Planning and designing play a key role in a teacher's lesson. "Planning must occur at the nexus of curriculum requirements, students' learning needs, available technologies affordances and constraints, and the realities of school and classroom contexts" (Harris & Hofer, 2011, p. 211). If planning of lessons does not occur or is done on a minimal scale, teachers will struggle to teach subject matter effectively or even find it problematic to know what methods to use when they are busy teaching. Angeli and Valanides (2009) explained that teachers must be able to design appropriate lessons by understanding what their learners' needs are during a lesson, what is required of them from the curriculum and what teaching methods and resources they are going to use to teach subject matter to the learners with multiple proficiencies.

The second knowledge domain making up the TPACK-P framework is assessment. This domain involves assessing how learners are using multiple techniques to construct knowledge (Yeh, Hsu, Wu, Hwang, & Lin, 2015). Various forms of assessment can take place in the classroom and it includes informal assessment that can be questions asked during the lesson to individual learners and worksheets and formal assessments that include your formal tests and tasks. Yeh et al. (2015) explained that "formative assessments inform instruction and empower learning since it provides checkpoints and feedback for teachers and preservice science teachers" (p. 79). After a topic is explained to learners, teachers can set up a test or even worksheets to assess learners' understanding. When those assessments are marked, teachers can clearly see the concepts that learners struggle with and need revision on as well as the concepts that learners have a good understanding of.

Assessments do not necessarily have to be a test or worksheets but can also include the use of practicals and simulations to demonstrate learner understanding. Technology can be used to continuously assess the learners in a lesson on concepts that pose a problem. One of these simulations can be using PhET that demonstrate Physical Science and Life Science experiments without physically doing the experiment itself. PhET is interactive simulations for mathematics and science that were developed by Carl Wieman at the University of Colorado in 2002. These simulations are freely available on the PhET website for teachers to use in their teaching. Learners can use different variables in the practical to observe what effect each of the variables will have on the experiment. This allows misconceptions that might arise during the teaching of the concept to be cleared up. During the use of these simulations, learners can answer different questions relating to these simulations on a worksheet that can be used by teachers for assessment purposes.

The last knowledge domain is that of practical teaching. Shulman (1986) defined practical teaching as the "wisdom of practice" (p. 9). Practical teaching can be explained as the knowledge teachers have on the practical implementation of ICTs in the classroom. In science education, teachers cannot rely on theoretical knowledge alone; practical application of the theoretical knowledge plays an important part in learners' understanding of concepts. Yeh et al. (2015) stated that "science teaching needs to guide and support students as they explore nature and make inquiries" (p. 80). With the use of ICT in the classroom, learners will be able to visualise nature itself through the use of pictures and videos. When teaching ecology, going out and using the environment gives learners physical experiences of nature that can make the understanding of terminology used more understandable. Concepts within science need to be practically implemented in the classroom to ensure that learners grasp the content. Even though chemicals are expensive for some schools, the use of technology can improve the practical teaching of some practical concepts. Teachers do not have to rely on the use of chemicals to demonstrate the effect to learners. Yeh et al. (2015) explain that "ICTs offer stimuli, representations, and channels to accommodate preservice science teachers with heterogenous cognitive development in different inquiry activities" (p. 80).

Considering the three domains of knowledge that make up the TPACK-Practical framework, the domains can be further refined and demonstrate eight knowledge constructs or phases. The eight knowledge constructs that make up the knowledge domains are as follows:

1. Using ICTs to understand preservice science teachers;
2. Using ICT to understand subject content;
3. Planning ICT-infused curricula;
4. Using ICT representations;
5. Using ICT-integrated teaching strategies;
6. Applying ICT to instructional management;
7. Infusing ICT into teaching contexts; and
8. Using ICT to assess students (Yeh et al., 2013).

The TPACK-P model's eight knowledge constructs relate to their knowledge domains as demonstrated in Figure 2.4:

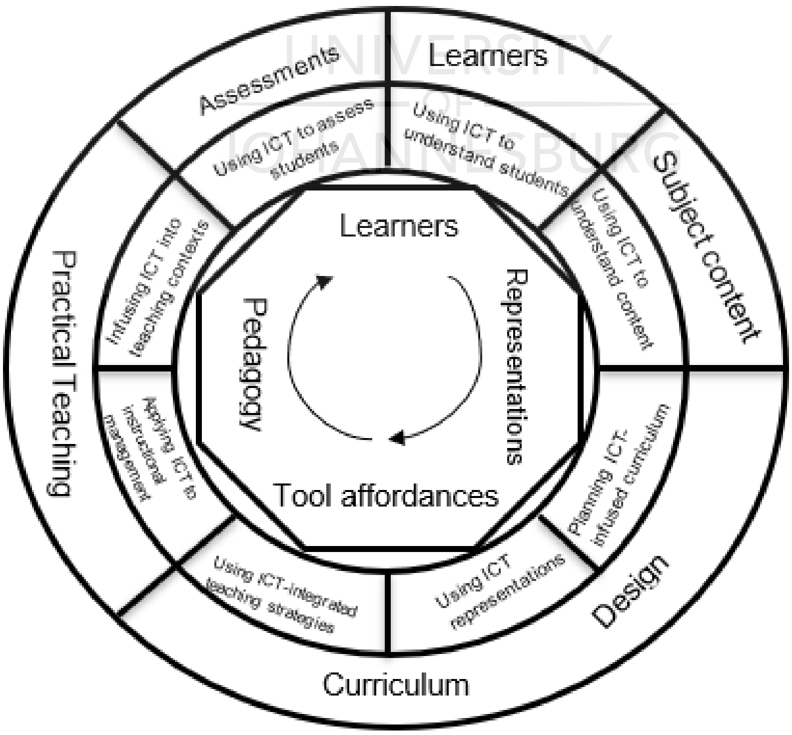

Figure 2.4: The framework of the TPACK practical model

(Adapted from Ay et al. (2015))

As seen in Figure 2.4, the eight knowledge dimensions found in the middle of the model were developed from five pedagogical areas used by teachers. The five pedagogical areas mentioned are: (i) practical teaching, (ii) curriculum design, (iii) subject content, (iv) learners and (v) assessment.

2.6 Benefits of ICT integration in science teaching

Several positive benefits can be identified when teachers are implementing ICT in the science classroom and doing so successfully. The first and most important benefit of using ICT is building of the confidence of teachers. Teacher confidence in ICT will improve usage of ICT, as well as the attitude towards ICT. The more teachers use ICT in the classroom, the more confident they become and the more their TPACK-P proficiency will improve and develop. With teachers increasing their confidence in using ICT in the science classroom, lessons can become more interesting and teachers can implement better applications to demonstrate abstract content to learners. If there is no confidence at all teachers revert to the traditional ways and learner understanding might be low, due to limited visual demonstrations of difficult concepts, thus causing less learning to take place. Mumtaz (2000) stated that teachers who are already using ICT at home and at school have a lot of confidence and even consider the use of ICT in their future lessons as a possibility. Teachers' confidence in teaching with ICT increases and several factors can be contributed to this improvement; lessons produced using ICT become more interesting to the learners, and learners are therefore more motivated and eager to learn science; they attend and listen in the science classrooms because the lessons are more stimulating and visual (Mumtaz, 2000). The use of ICTs in the classroom will not just improve lesson presentations by teachers but classroom atmosphere for the learners, also improves a teacher's capabilities in searching for better resource material to use and their effectiveness in doing administrative tasks (Mumtaz, 2000). The use of ICTs can also motivate teachers in becoming lifelong learners by building on their prior knowledge and skills.

Considering the benefits brought by ICT integration in the science classroom, Moseley and Higgins (1999) discussed the same benefits that ICT has on science education. They produced a list of several characteristics that teachers fulfil when they successfully make use of ICT in their classroom. This relates with the list set by

Mumtaz (2000). These characteristics will only benefit the integration of ICT in the classroom. The primary characteristic teachers have that will benefit the integration of ICT in the classroom, is the attitude they show towards the use of ICT. A positive attitude will improve a teacher's use of ICT in the classroom. The next characteristic is a learner-centred approach in the use of ICT in the classroom. When learners are the focus of a teacher's teaching strategy in the classroom the implementation of ICT will be more imperative. The next characteristic is the "pupil choice rather than teacher direction" (Mumtaz, 2000, p. 328). The teaching of content that will focus more on the approach of the learners choosing topics than that of the teacher, will improve the use of ICT and make the lesson more interesting. Implementing knowledge structures where learners want to know more and are fascinated about this, makes a lesson more interesting and they become more knowledgeable about it through experience. The last characteristic is the "preference for individual study rather than pupils receiving instruction" (Mumtaz, 2000, p. 328). Learners want to learn more on topics and if teachers only teach constantly, learning will not be effective. Learners want to learn more about things that are fascinating to them and not just the knowledge that teachers are providing to them. Applying practical skills in the classroom or making use of simulations, learners will learn more and observe more. They will understand that changing variables of an experiment will change the outcome of an investigation, internalising that knowledge for long-term use.

The implementation of ICT does not always have to be a negative aspect for a teacher but must rather be viewed as a positive aspect with several benefits for learners learning science. With technology teachers can do so much more than just the conventional method of teaching. With technology, teachers can show learners videos and documentaries on different topics to awaken interest but also to demonstrate how the abstract concepts function and come together. With regard to the topic of poaching of animals, constantly mentioned in the news, a documentary demonstrating what impact the animal has on the ecosystem and how the environment will be affected when the animal is killed, can have a positive impact on a learner and learners will start seeing why conservation is such an important project.

With the limitation of resources when it comes to doing practicals as well as the substantial number of learners per classroom, using various software programs available to simulate the practical, all learners will be able to see and not feel left out because of limited resources and space. The experiment can also be done with learners without them wasting time or feeling nervous. Stott (2010) described and discussed various advantages in the use of ICTs in scientific investigations and in the classroom. The first advantage is the saving of time and the reducing of cognitive workload. With the use of ICT, learners do not have to wait for a whole period to have water boiled for the experiments or chemicals heated up enough to demonstrate the difference, for example with the test for glucose. Fehling's A and B is mixed with a glucose solution and is then heated up to demonstrate whether glucose is present or not. With the use of simulations, the demonstration will be much faster and more effective because learners do not have to wait for the heating, and they can concentrate on what happens during the simulation experiment and observe the necessary changes.

The second advantage is the "exploration of topics that are impossible to do with traditional laboratory experiments" (Stott, 2010, p. 167). Not all schools have the resources available to do proper experiments with learners and learning will not take place effectively due to a disassociation when it comes to real life. A good example is DNA profiling. DNA profiling entails DNA to be extracted from blood and a polymerase chain reaction technique will be used for this. These techniques and machines are resources that are not found in a traditional classroom, and the use of simulations in this regard or even videos will be more effective. The third advantage of using ICT in the classroom is in improving learning quality. With the use of ICTs teachers can show learners videos, documentaries, films, as well as different pictures to demonstrate content to learners. These ICTs lighten up the classroom atmosphere and make the work more enjoyable to learners. When work is enjoyable, learners will be motivated to do better and improve their marks. When learners are motivated to study, learning quality improves and teachers also enjoy what they do.

Using various software that demonstrates simulations of various practicals, learners can constantly change various variables and see what effect it will have on the outcome of the experiment. Using ICT will also improve the scientific literacy of learners in the classroom, increasing their learning and improving results. Sheffield Dobozy, Gibson, Mullaney and Campbell (2015) explained that technology has a big influence on the teaching and learning activities that take place in a classroom. When technology is used sufficiently, lessons will be more interesting, and learning will be more effective over the long term.

With technology developing every day, a rich amount of information becomes available to teachers to make use of in their classrooms. Yeh et al., (2014) discussed the importance of having such a rich abundance of information available from the internet and applications. It is an advantage that teachers will experience when they have access resources for information, allowing them to update their own CK and accommodate all the learners they have in front of them in the classroom. Learners coming into our classrooms have a vast amount of knowledge on indigenous knowledge and customs taught to them by their parents, grandparents and community, that some of this knowledge might contribute to misconceptions they might have on science. The knowledge explained by their family is from a distinct perspective in relation to science and this contributes to learners not understanding what science entails. With the use of ICT, a large amount of information is available on different topics that teachers can use in the classroom to clear the misunderstandings learners might have and to demonstrate to them to correct their scientific understanding. Teachers can therefore ensure that learners receive the same knowledge in the classroom and build on the previous knowledge they have. Stott (2010) defined simulations as "electronic representations of physical phenomena" (p. 163). With simulations, teachers can demonstrate phenomena that occur in nature itself, without needing or having any resources available to them in the classroom.

2.7 Barriers experienced with the implementation of ICT

Teachers experience various barriers to the implementation of technology in their classrooms. The main barriers that will form part of this section are teaching experience, the fear of change in the methods of teaching and confidence of teachers. The different inhibitors identified by different researchers will form an essential part of the discussion on the different barriers that are experienced by teachers when it comes to the implementation of ICT in the classroom. Technology use is not part of all teachers' skill set and can pose various challenges to teachers who did not receive any training on the implementation or experience in using it. Yeh et al. (2015) stated that "the more successful teaching experiences that teachers accumulate, the more resources they can use to build their confidence for accomplishing instructional tasks, such as tackling the complexity when teaching with ICT" (p. 88). Teachers need to implement technology in the classroom to start building their confidence on the use of it, without feeling that they lack the necessary experience in doing so, it must be seen as a positive implementation. "Teaching experience can be viewed as a major contributor; explaining the transformation of TPACK or PCK from theoretical knowledge to practical knowledge" (Van Driel, Beijaard, & Verloop, 2001; Van Driel et al., 1998). Yeh et al. (2015) also stated that when a teacher successfully implements technology in their teaching, a positive influence can be experienced in the teacher's quality of teaching.

The research done by Mumtaz (2000) provided a list of inhibitors that had been observed in previous studies done by Rosen and Weil (1995), Winnans and Brown (1992), Dupagne and Krendl (1992), Hadley and Sheingold (1993), that prevented teachers from implementing ICT successfully in their teaching. Inhibitors that contribute to the ineffective use of ICTs is the "lack of teaching experience with ICT, lack of on-site support for teachers using technology, lack of supervision of children when using computers, lack of ICT specialist teachers to teach students computer skills, lack of computer availability and lack of financial support" (p. 320). If there is no financial support available to the teacher, whether it is through the school or personally, the implementation of technology will not be a necessity for the teacher. Mumtaz (2000) also stated that a "lack of computers and software in the classroom can seriously limit what teachers are able to do" (p. 336). If there are no computers available to the teachers, implementing of ICT will rarely take place and the teacher must rely on the conventional method of teaching, whether it is a blackboard or the use of transparencies.

Research shows that a teacher's TPACK-P is influenced by the necessary teaching experience they have. In-service teachers will have much more experience when it comes to teaching of subject content to learners, using a variety of teaching methods, but with the use of technology in lessons they can be ineffective and inexperienced. Jen et al. (2016) explained that even though the support may be present and "ICT tools are available to them" (p. 58), teachers lacking in actual experience when it comes to technology-assisted teaching will negatively impact their development of

TPACK-P. Van Driel et al. (1998) also discussed that experience that teachers have in teaching with ICT is one of the main contributors to the gaps that have been found between learning and teaching, as well as between novice teachers and experienced teachers. Yeh et al. (2014) described that in-service teachers make use of technology to develop worksheets, assignments and tests, but the implementation of technology regarding the use of PowerPoint presentations, videos or even simulations will be a limited aspect in their use of ICT.

Bingimlas (2009) explained that there are several factors that might contribute to either the successful implementation of ICT or the lack thereof, for example the attitude (internal drive) of the teacher towards the use of technology in the classroom and the confidence of a teacher in the implementation of ICT's. If teachers have a very negative attitude towards using technology, the implementation thereof will never take place and teachers will fall back onto the use of the conventional method of teaching. Afshari, Bakar, Luan, Samah, and Fooi (2009) and Mumtaz (2000) explained that the lack of necessary knowledge of teachers and their confidence will be able to explain the low use of technology as well as its ineffective use in classrooms.

Mishra and Koehler (2006) further explain that teachers must do more when they are acquiring new skills in using the tools that are currently available to them; "they will also have to learn new techniques and skills as current technologies become obsolete" (p. 1023). Teachers must constantly develop new techniques in using technology in the classroom, due to the transient nature of today's technology. As technology changes, teaching methods change. If some teachers do not change, the development of their TPACK-P will lag behind and teaching approaches will stay the same, whether it is helpful or not. Mishra & Koehler (2006) also explained that not all the teachers have welcomed the use of technology in the classroom and a range of reasons can be provided for this. One of the reasons is the fear of change. Teachers that have been in the teaching profession for a long period of time have adapted to change in curricula and stand by their methods of teaching whether it includes technology or not. If a new approach is introduced to teachers, a negative view can develop due to the lack of experience and the fear of changing what they already know.

Mumtaz (2000) agreed on the barrier of "fear of change" that teachers develop when it comes to the implementation of new skills and explained that teachers that are resisting change are not necessarily against the change in classrooms, but they are "often expected to lead developments when they are given insufficient long-term opportunities to make sense of the new technologies for themselves" (p. 321). If they are required to implement technology in the classroom, teachers need to attend workshops or different courses that will demonstrate the use of ICT. Sometimes teachers even need to lead these workshops on how to use ICT in the classroom, even if they are not confident enough in implementing it in the classroom themselves. A common reason for not attending workshops on ICT implementation provided is lack of time. If we consider the time teachers have at school for teaching as well as doing administrative tasks, a lack of time will always be a barrier.

Koehler et al. (2013) explained that there are several factors, social and contextual, that influenced the use of ICT. They explained that the social and contextual factors "complicate the relationships between teaching and technology" (p. 14). In relation to all the above researchers, Koehler et al. (2013) also stated that "teachers often have inadequate (or inappropriate) experience with using digital technologies for teaching and learning" (p. 14). Having no experience in using ICT can be a difficult skill for teachers to develop without having the necessary training. Koehler et al. (2013) stated that "acquiring a new knowledge base and skill set can be challenging, particularly if it is a time-intensive activity that must fit into a busy schedule" (p. 14).

2.8 Role of tertiary institutions in developing ICT confidence in preservice science teachers.

Tertiary education institutions have the responsibility of ensuring that their preservice science teachers develop the necessary knowledge on how to integrate technology-assisted teaching in the classroom. Preservice teachers might have a suitable lesson plan on the integration of technology in the classroom, but on implementation, the preservice student will lack experience in relation to in-service teachers. Researchers in numerous studies have agreed that practical experience with ICT will play a critical role in the implementation of technology in the classroom (Yeh et al., 2015; Yeh et al., 2014). If a preservice teacher does not have the necessary practical experience in implementing ICTs in the classroom, the implementation thereof in the classroom will be difficult to adapt to when they become in-service teachers.

In South Africa, tertiary institutions send preservice science teachers on school experience to gain experience on the conditions in our schools, as well as the classroom environments. During this school experience timeframe, which can last as long as eight weeks, preservice science teachers must teach multiple lessons in a subject major. During these lessons the mentor teacher will guide the student on the practical implementation as well as the different teaching methods they can use during a lesson. When the preservice teachers are not out on the practical experience, institutions make use of micro-lessons to help preservice science teachers develop the necessary experience on the use of ICT in the classrooms. Yeh et al. (2015) explained that teaching programmes that include practical experiences in schools as well as the use of micro-lessons will produce teachers that are effectively equipped to use ICTs in the classroom. Therefore, the more experience preservice teachers have in the use of ICTs as a teaching aid, the more they will develop their TPACK-P proficiency.

Preservice science teachers are not yet fully part of the teaching environment that will allow them to build up experience and therefore the use of micro-lessons, the designing of lesson plans and school experience will allow them to develop the necessary skills to apply in the classroom. Yeh et al. (2015) explained that in-service teachers will be able to refine their knowledge through physical teaching experience in their classroom, adjusting the way they teach different subject matter, while preservice science teachers will only be able to develop the knowledge in-service teachers have through the micro-lessons and school experience. During the micro-lessons, preservice science teachers have ten to 15 minutes to teach the introduction, the body and the conclusion of the lesson, demonstrating what they will be doing during the lesson, what models or technology they will be using and how they will assess learners on the topic taught on that day.

2.9 Conclusion

A teacher's TPACK-P plays a significant role in the classroom. It enhances the learning quality, allows teachers to simulate experiments that are not done in a traditional laboratory and is time saving. Considering the research done on TPACK-P framework and importance thereof, teachers need a good TPACK-P to ensure effective use of ICT in the classroom. TPACK-P framework is built on knowledge systems teachers must possess such as PK and CK. As seen in the literature review above, various barriers to the implementation of ICTs have been identified. To improve teaching and learning in a classroom, teachers and management will have to consider these barriers and try to remove them.

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter describes the research paradigm, the research design, sampling, methods of data collection, data analysis and ethical considerations. This research study was designed to answer the main question: What is the TPACK-P proficiency of preservice science teachers?

This chapter provides an argument for the researcher's choice of research paradigm, research approach and research design to address the above research question.

3.2 Research paradigm

A research paradigm is defined as a "constellation on beliefs, values, techniques and so on shared by members of a given [scientific] community" (Kuhn, 1970, p. 175). They tend to reflect the interests and the focus of the research communities whereby they will share a set of theory-informed beliefs about the social world (Matthews & Ross, 2010). A paradigm can also be defined as a "map, helpfully directing us to the problems that are important to address, the theories that are acceptable, and the procedures needed to solve the problems" (Marlow, 2001, p. 7).

The paradigm that will support my research as a theoretical framework is that of pragmatism. The pragmatism approach is associated with mixed-methods research. In this research approach, the focus is primarily on the research question asked than on the methods that are used in this research. According to Creswell (2003), Cherryholmes (1992) and Murphy (1990), pragmatism provides a basis to the following knowledge claims: When researchers are engaged in their own research, they draw profusely from the qualitative and quantitative data. Researchers have a freedom of choice on what methods to use in their research as well as different techniques and methods. The world is not seen as an absolute unity. In mixed-methods research, researchers make use of many methods to collect and analyse their data. Using both qualitative and quantitative data to provide a better understanding of a research problem. Pragmatism researchers look to the "what" and "how" in research, and where they want to go with it. Mixed-method researchers needs a purpose for their research and why is better to make use of both qualitative and quantitative. Pragmatists agree that research occurs in social, historical, political and other contexts. In mixed methods, postmodernism is included. It is a theoretical lens that is a reflexive of social justice and political aims (p. 11).

3.3 Research design and methodology

The quantitative approach is an approach were the researcher is “developing knowledge, employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data” (Creswell, 2003, p. 18). In the qualitative approach, the researcher collects “open-ended, emerging data with the primary intent of developing themes from the data” (Creswell, 2003, p. 18).

The explanatory sequential design takes place in two distinct phases. The research design starts off with the collection of the quantitative data and the analysis thereof. After the collection of the quantitative data through questionnaires, qualitative data is collected and analysed. Qualitative data collection is designed to probe deeper into the understanding of the questions answered by the participants in the study. The quantitative and qualitative data that has been collected is of importance because it addresses the research question of the study.

This research follows an explanatory sequential mixed-method design (Creswell, 2014). This design involves a “two-phase project in which the researcher collects qualitative data in the first phase, analyses the results, and then uses the results to plan (or build onto) the second qualitative phase” (Creswell, 2014, p. 224). It is considered explanatory because the initial quantitative data results are explained with the qualitative data. It is sequential because the quantitative phase is followed by the qualitative phase.

Creswell and Plano Clark (2010) presented explanatory sequential design as follows:

Figure 3.1: Prototypical version of Explanatory sequential design

Qualitative methods are used after quantitative methods to enable the researcher to explore some of the issues that were raised in the quantitative data collection. These issues can be explored in more depth and provide a better understanding of answers provided by the participants.

Johnson, Onwuegbuzie and Turner (2007) define mixed methods as “a type of research in which a researcher or a team of researchers combines elements of qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and corroboration “(p. 123). In mixed-methods design, the researcher collects and analyses persuasively and rigorously both qualitative and quantitative data.

The reliability of a study means the consistency, the validity and the accuracy of the study (Adams & Lawrence, 2015). Both reliability and validity play a significant role in any research process. Reliability can be defined as the “expectation that we will find similar results when we repeat a study” (Adams & Lawrence, 2015, p. 70). To ensure that a study is reliable, repetition is needed.

To ensure that the data provided for the research is valid, multiple ways of gathering this data can be implemented. The process researchers use to ensure validity is known as “triangulation” (Matthews & Ross. 2010, p. 145). Triangulation can be defined as a “way of checking out insights gleaned from different informants or different sources of data” (Taylor, Bogdan, & DeVault, 2015, p. 94). Matthews (2015) also explained that researchers who use multiple ways of gathering data to help them to answer their research question will enable them to check the validity of their data.

Triangulation took place in this study using interviews to ensure that the data provided by the preservice science teachers in the questionnaire is valid and that they understood what the questions expected from them.

This study adhered to the reliability and validity check for qualitative data as suggested by Merriam (1998). This elaborated in section 3.3 of this study.

1. *Triangulation:* I used questionnaire and interview data to build a coherent justification of the emerging findings.
2. *Member checks*: I checked data and tentative interpretations with the preservice teachers.
3. *Peer review*: There was ongoing dialogue and critical reflection with other researchers on the research process and tentative interpretations.
4. *Reflexivity*: Critical self-reflection was done regarding anything that may bias my interpretation, like hidden assumptions, own worldview, theoretical orientation and interrelationships with the teacher.
5. *Audit trails*: I provided a detailed account of methods, procedures and reasons for decisions.
6. *Rich description*: I provided a detailed description of events to enable readers to contextualise the study and judge the extent to which the findings could apply to their situation.

3.4 Context of the study

The study was conducted in the Faculty of Education, University of Johannesburg with third- and fourth-year preservice science teachers in Physical Sciences, Life Sciences and Natural Sciences. These students are all studying towards a bachelor's degree in Further Education and Training with Physical science, Life Science and Natural Science as one of their modules. Many students will have two of the mentioned modules above as both their modules or students have one of the modules alongside Mathematics, Geography and Physical Education. Within Life Science, Physical Science and Natural Science modules, ICT is addressed as a separate topic and multiple ideas are provided to students on how to implement ICT within their specific module.

3.5 Population and Sample

3.5.1. Population

The population comprises all 200 third and fourth year Natural, Life and Physical Science students. All these students were given a questionnaire. Only 103 returned the questionnaire (rate of return is 52%)

3.5.2. Sample

Convenient sampling was used in this study. The 103 that returned the questionnaire conveniently formed the sample. The first phase of the research involved collecting quantitative data from a sample of 103 Life, Natural and Physical Science preservice science teachers in their third and fourth year of study. The sample was selected by applying the technique of convenience sampling as the preservice science teachers are located at the same university where I am registered for my own study, and this accommodated easy access to the sample. According to McMillan and Schumacher (2010), convenience sampling can be defined as "a group of subjects is selected on the basis of being accessible or expedient" (p. 137). This type of sampling is used in quantitative and qualitative studies because the researcher may experience "practical constraints, efficiency and accessibility" (McMillan & Schumacher, 2010, p. 137)

Table 3.1 illustrates the distribution of the 103 preservice science teachers who participated in this study according to their subject majors.

Table 3.1: Student profiles

Major subjects	Number in sample	Percentage of sample (%)
Physical Sciences only	37	35.9
Life Sciences only	42	40.8
Natural Sciences only	1	1.0
Both Physical Science and Life Science	20	19.4
Both Life Science and Natural Science	2	1.9
Physical Science, Natural Science and Life Science	1	1.0
Total	**103**	**100%**

3.6 Methods of data collection

3.6.1 Questionnaires

According to Adams & Lawrence (2015), “Questionnaires allow participants in a study to respond to a question that relate to a particular topic in their own way” (p. 2015).

There are several types of questionnaires that can be used in quantitative studies. “Questionnaires are usually used when a random sample has been drawn from a population, or using a quota sample” (Matthews, 2010, p. 205). Within these questionnaires, questions or statements used by the researcher, are worded in different ways to allows different responses. According to McMillan and Schumacher (2010) the first type of questionnaire contains open and closed-form items. When predetermined responses have been provided to the participant of the research study, the questions will be known as closed form, as we see in this study of TPACK-P of preservice science teachers. Closed-form questions can also be used to determine study year, subjects, gender or any demographic information of the participants of the study and be categorised accordingly, making data categorising easier for the researcher. In open-ended questions or items, the participant can give their own responses to the questions being asked. In this study, closed-form items on the questionnaire (Appendix C) are much easier to use since there are four different proficiency levels, and a level for each of the participants needs to be determined. Seventeen items with different instructional scenarios are also used, making it easier to categorise and determine the proficiency level. Questionnaires should be anonymous, but Appendix C requires students to provide their name.

The second type of questionnaire contains scaled items. Scaled items are defined by McMillan and Schumacher (2010) as “a series of gradations, levels, or values that describe various degrees of something” (p. 198). Within the scaled items, participants of a study are provided with a questionnaire, where they must place a tick or a cross on the scale that “reflects their beliefs or opinions about the statement” (McMillan & Schumacher, 2010, p. 198). A good example of a scale item and the most widely used example is that of the Likert scale. The Likert scale can be defined as a scale where the “stem includes a value or direction and the respondent indicates agreement or disagreement with the statement” (McMillan & Schumacher, 2010, p. 198). In the

Likert scale, the participant can check whether they strongly agree, agree, neither agree nor disagree, disagree or strongly disagree with the statement that has been provided to them.

The questionnaire (see Appendix C) used in this research was developed by Yeh et al. (2015) during a study of teachers' TPACK, using the Delphi survey technique. The questionnaire comprises 17 items that describe the instructional scenarios on science teachers' implementation of ICTs in their instruction. These items are closed-form questions, meaning that respondents could not provide free-form answers. Four predetermined instructional scenarios are provided to them to choose from and they need to choose the one most suitable to them.

Hence, the items solicit data on teachers' TPACK-P proficiency levels. This instrument has been administered previously to preservice teachers (Jen, Yeh, Hsu, Wu, & Chen, 2016), and is deemed appropriate for the targeted sample in this study. Prior to this study, the questionnaire was piloted with a group of 10 university preservice science teachers. The readability of the items was confirmed through interviews. The items in the questionnaire have been clustered together according to the three knowledge dimensions that were mentioned in the previous chapter. Questions one to six focus on the assessment dimension of the preservice science teachers. Questions seven to 13 address the planning and designing knowledge dimension. Lastly, questions 14 to 17 solicit data on the enactment knowledge.

Each item has four options that individually represent typical performances that teachers at levels 1 to 4 display. Level 4 (reflective application) is the highest proficiency level that science teachers could achieve, and it indicates that they are adept at using their experience-based TPACK to employ ICTs in assisting their learners in learning about science. Teachers at level 3 (infusive application) use ICTs to guide preservice science teachers to self-explore and independently construct their science knowledge, whereas teachers at level 2 (simple adoption) use ICTs to help learners learn about science via more teacher-centred strategies or with less well-founded rationales. Level 1 represents teachers that only have a basic understanding of technology, resulting from their limited experience (or lack thereof), negative impressions regarding technology in the classroom, or a lack of intention to implement ICTs in their classroom.

Table 3.2 demonstrates how the 17 items of the questionnaire were divided up into the three different knowledge domains of TPACK-P, known as planning and designing, practical teaching and assessment.

Table 3.2: Item indicators under the three knowledge domains of TPACK-P of science student teachers

KNOWLEDGE DOMAINS		
Planning and Designing	**Practical teaching**	**Assessment**
7. Learning about subject content using technology.	14. Why technology-supported instruction is considered special.	1. Use of video's/ animation in the classroom helps to better understand student learning.
8. Types of subject content suited to teaching with technology-supported instruction.	15. Opinion regarding synchronous and asynchronous communications.	2. Simulations help to identify learning difficulties.
9. Factors influencing teachers planning and designing of technology-supported instruction.	16. Handling of problems with technology-supported instruction.	3. Usefulness of technology integration helping preservice science teachers with different learning styles and needs.
10. Instructional objectives appropriate for technology-supported instruction.	17. Opinions about applying technology to instruction management.	4. Teacher understanding of technology-supported assessments.
11. Selecting appropriate technology tools for content presentation.		5. Distinctive features of technology-supported assessments
12. Selection and use of teaching strategies to assist technology-supported instruction.		6. Teacher's use of technology-supported assessments to evaluate preservice science teachers in science instruction.
13. The effects of group collaborations coupled with technology-supported instruction.		

3.6.2 Interviews

Interviews that are used in any research study, will fall under the qualitative method of research. With interviews, researchers can obtain "thick and rich data" (Turner, 2010, p. 754).

According to Matthews (2010), interviews are a data collection method which will:

- Facilitate the direct communication between the researchers and interviewees, whether it is face to face or at a distance using a telephone or the internet.
- Enable the interviewer to prompt information, feelings and opinions from the interviewees by making use of questions and interactive dialogue.

According to Matthews (2010), interviews are also used in in two different ways:

1. The structure and standardisation between and within different interviews differ. Three types of interviews are found that are discussed later.
2. The researcher and the participants play different roles in the interviews.

Three different formats of interviews, as mentioned above, can be used during a research study: a) informal conversational interviews; b) general interviews guided by a structural approach; and c) standardised open-ended interviews (Turner, 2010). During the informal conversation interview, questions are generated spontaneously during a natural setting (Turner, 2010). During these conversations, researchers will not ask the participant any specific questions, but will rely on the conversation they have with the participant during class time or just in public. The general interview guide approach, a structural process is followed. The general interview guide can be seen in the same light as semi-structured interviews. Questions in this type of interview are more structured but allow a researcher to adapt to the answers that have been provided by the participant (Turner, 2010). During this interview the researcher can also ask the participant to elaborate more on the answer they have provided. Lastly, the standardised open-ended interviews are highly structured. All participants in the study are asked the same type of questions. The questions asked are open-ended and allow participants to add as much information as needed by the researcher and are therefore not limited (Turner, 2010). These questions also allow the researcher to probe deeper into the answers that have been provided by the participant.

Semi-structured interviews are used by many researchers in multiple study fields. If we consider the classification by Turner (2010) of different interviews above, Matthews (2015) explains that semi-structured interviews used by many researchers:

- Have a common set of topics or questions available for each specific interview;

- Introduce topics and questions in different ways that are appropriate for each interview; and
- Allow the participant to answer the questions in his/her own way, using their own words.

Researchers use semi-structured interviews in their research, due to the interest in people's experiences, behaviour and understanding of different topics or specifically the topic they are busy researching (Matthews, 2010).

During this research, semi-structured interviews with open-ended questions were used. Each of the chosen participants in the qualitative phase had the same set of questions asked in different ways, relating to the answers they provided on the questionnaires during the quantitative research. Use of student's own questionnaire as a semi-structured interview as a basis and allowing student to elaborate further. The questions asked, probe deeper into the answers provided on the questionnaire to get a better understanding of the preservice science teacher's understanding of TPACK-P.

3.7 Procedure for data collection

The data collection proceeded in two phases which reflected the explanatory sequential mixed-methods design that was adopted for this research.

The first phase of the research involved collecting quantitative data from a sample of approximately 200 Life, Natural and Physical Sciences preservice science teachers in their third and fourth years of study.

3.7.1 Phase One: Administering the questionnaires

The questionnaires were administered to the 200 preservice science teachers during their different module lectures. They answered the questionnaires during the different module lectures and continued after the lectures if they were not finished. The preservice science teachers were provided with the instructions on the answering of the questionnaire. They needed to indicate whether they were third-year or fourth-year preservice science teachers, their major subjects as well as their qualifications. When they needed to answer the questions, they had to circle the letter most suitable to their understanding of the question.

3.7.2 Phase Two: Interviews

The second qualitative phase of this study involved interviewing third- and fourth-year preservice science teachers, who were purposefully selected from the quantitative survey sample of the first phase. The respondents from the quantitative phase were grouped into categories, based on their TPACK-P proficiency levels and three representative individuals per group were randomly chosen for qualitative data collection. Individual interviews were used to probe deeper into the answers the teachers provided on the questionnaire. The interviews were audio-recorded and transcribed. Interview data was coded and classified (Babbie & Mouton, 2009) through a process guided by trends and patterns, which would have emerged from the analysis of the questionnaire data, in relation to integration of ICT in science teaching. Only one individual was allocated to the proficiency level 1 and therefore, instead of 12 individuals, only 10 Preservice science teachers were chosen in the end for the interviews. Due to the availability and schedules, only 5 preservice science teachers were interviewed for this study.

3.8 Data analysis

Knowledge differences between the 103 preservice science teachers were explored by applying a multidimensional Partial-Credit Model (PCM) to the response data collected. All responses on the 17 questions were scored according to the corresponding proficiency level (i.e., 1, 2, 3, 4). A blank response was scored as 0, referring to proficiency level 0 where “the respondent had no idea how to use technology in a science class” (Jen et al*.,* 2016, p. 51). The proficiency level for each of the 17 questions were located between 0 and 4. Each option chosen by the student, represented a score between 0 and 4. Each student provided 17 responses for the 17 questions, that could be used to estimate their knowledge of TPACK-P.

The data collected were analysed using item response theory (IRT), by employing Rasch modelling. A blank response provided by preservice science teachers, was coded as 0. The coding of 0 represented proficiency level 0 in this study. Proficiency level 0 represented that the “respondent who had no idea how to use technology in a science class” (Jen et al., 2016, p. 51). The four options for each item were designed to represent the four proficiency levels. Proficiency level 1 was coded 1, proficiency level 2 as 2, proficiency level 3 as 3, and proficiency level 4 as 4.

The Rasch analysis does not require the student to answer all the items in the questionnaire and preservice science teachers can still be compared on a “single equal-interval scale” (Boone, 2014, p. 8). For this study the single equal-interval scale that preservice science teachers were compared with, is that of their proficiency level in their knowledge of TPACK-P. We then used the multidimensional PCM to produce a WrightMap. If we consider the questionnaire that was used within in this study, students had to select an option that they agree with more in relation to the instructional scenario’s that were provided to them. There was no right or wrong answer within this questionnaire. Kelderman (1996) explained that “responses to educational and psychological test questions can be scored partially correct rather than simply correct or incorrect” (p. 155). The multidimensional PCM was formulated “for data in which different answers depend on different traits” (Kelderman, 1996, p. 155). According to Yao and Schwarz (2006) the “multidimensional item response theory is a generalization of unidimensional IRT that describes the interaction between a person and a task where the characteristics of the person are described by a vector of constructs” (p. 469). The IRT model fit is measured and “multidimensional statistics have been used within the IRT framework to further describe the characteristics of items and tests” (Yao et al. 2006, p. 470). What makes the multidimensional PCM a suitable model to use in producing a WrightMap, is the fact that it “has the useful property that response alternatives can be compared independently of the person, and persons can be compared independently of the alternatives, provided that both responses depend on the trait of interest” (Kelderman, 1996, p. 156).

A WrightMap was devised by the Rasch experts Benjamin Wright and Mike Linacre (Boone, 2014). A WrightMap was previously known as the person-item map and is used to display “very complex rating scale data and test data” (Boone, 2014, p. 112). WrightMap allows the Rasch results of the study to be shared with researchers and for those who are unfamiliar with the concept of Rasch modelling, to be able to “digest the results and make sound decisions about complex data” (Boone, 2014, p. 8). The WrightMap also allows the researcher to evaluate how the items of the questionnaire completed by the participants of the study, define traits sufficiently as well as swiftly (Boone, 2014). Preservice science teacher's ability can also be estimated with weighted likelihood ability estimates. Weighted likelihood estimates were proposed by Warm (1989), providing "a bias correction to the maximum likelihood method by solving a weighted log-likelihood equation" (Tao, Shi & Chang, 2012, p. 298). A WrightMap has two sides. The left side shows the distribution of the respondents weighted likelihood ability estimates (WLE) from the most able at the top to the least able at the bottom. The options of the items on the right side are distributed from the most difficult (highest threshold) at the top to the least difficult at the bottom. This explains that for each proficiency level 0-4 of the preservice science teachers TPACK-P, there will be an estimated mean.

The second qualitative phase of this study involved interviewing the science preservice teachers who will be purposefully selected from the quantitative survey sample of the first phase. Preservice teachers' different proficiency levels were identified, and ten preservice science teachers were selected for interviews. The interviews were used to probe deeper into the preservice science teachers' answers to the questionnaire to further illustrate preservice teachers TPACK-P. I will group respondents from the quantitative phase into categories based on their TPACK-P proficiency levels, and randomly choose three representative individuals per group for qualitative data collection.

3.9 Ethics

Ethics can be defined as "a set of rules by which individuals and societies maintain moral standards in their lives" (Matthews & Ross, 2010, p. 71). McAuley (2003) explained that "the ethics of social research is about creating a mutually respectful, win-win relationship in which participants are pleased to respond candidly, valid results are obtained, and the community considers the conclusions constructive" (p. 95).

During this research ethical approval was obtained first, before any data collection procedures could begin. The ethical clearance to conduct the research, was obtained from University of Johannesburg's Faculty of Education Research Ethics Committee. This committee ensures that the research complies with the ethical guidelines. The ethical clearance for this research was granted.

When ethical approval has been granted by the Faculty of Education Research Ethics Committee, the participants must give informed consent to take part in this research. Informed consent is defined as “an ethical standard by which potential participants are informed of the topic, procedures, risks and benefits of participation, prior to consenting to participate” (Adams & Lawrence, 2015, p. 6). The researcher must provide the participants with adequate information on the research and what the research is about. Participants must also know that they are participating voluntarily in this research and can withdraw at any time. Confidentiality of the participants also need to be assured by the researcher during the research, as well as afterwards. Participants’ in the research, privacy and dignity need to be respected and all the data that is collected, as well as the results need to remain confidential (Adams & Lawrence, 2015, p. 10).

Consent was obtained from the third- and fourth-year preservice science teachers who participated in this study. The intention and purpose of this study was clearly communicated to the preservice teachers involved. The participants were assured of the confidentiality of their participation and it was made clear that they could withdraw at any stage of the research.

3.10. Conclusion

In this chapter the research design and design followed in the study was explained in detail. The use of an explanatory sequential design that included two distinct phases of questionnaires and interviews were included in the explanation. The research paradigm that supported this research, pragmatism was described. With different paradigms being available for different research purposes, the pragmatism paradigm was the most suitable option for this research. The study was conducted in the Faculty of Education, University of Johannesburg with third- and fourth-year preservice science teachers in Physical Sciences, Life Sciences and Natural Sciences. The students had to complete a questionnaire to determine their TPACK-P proficiency level, and 10 were selected to participate in the interviews. As explained in the chapter, due to availability and schedules, only five preservice science teachers attended the interviews.

CHAPTER 4

RESULTS AND FINDINGS

4.1 Introduction

A total of 103 preservice physical, life and natural science preservice science teachers took part in this research. The preservice science teachers were third- and fourth-year preservice science teachers from the University of Johannesburg.

4.2 Theoretical framework used for data analysis

There are two types of analytical methods used to develop instruments to use in different research methods, IRT, that includes Rasch modelling, and Classical Test Theories (CTTs) (David, Hitchcock, Ragan, Brooks & Starkey, 2018). IRT can be defined as a “collection of mathematical models and statistical methods used for two primary purposes: item analysis and test scoring” (Thissen & Steinberg, 2012, 148). “IRT allows test-takers’ ability and the difficulty of certain performances at different proficiency levels for all task items to be located along the same scale” (Jen et al., 2016, p. 50). CTTs focus mainly on “samples with specific characteristics, given a particular set of items and total score; the implication being that the CTT results can be hard to generalize to other samples” (David et al. 2018, p. 78). IRT requires more focus on the individual item than the total score of the instrument” (David et al., 2018, p. 78). “IRT applications are typically used to develop items that measure some skill or ability and presentation of correct and incorrect answers” (David et al., 2018, p. 78). The PCM in the IRT, was applied to validate the framework of TPACK-P and set up the thresholds of the proficiency levels for the scales of science teachers.

4.3 TPACK-P Proficiency of preservice science teachers

Using Rasch modelling, the thresholds of the 17 questions were established using the WrightMap software. Figure 4.1 on page 54 demonstrates the proficiency levels for all 17 questions. In Figure 4.1, I provide questions 1 and 13 as examples to illustrate how the proficiency level for each option was identified. For most of the 17 questions, option C was selected by the preservice science teachers as the best option to use in the instructional scenarios that were provided to them. For most of the 17 questions, option D was chosen as a not suitable option to use within these instructional scenarios. Considering question 1, the highest proficiency level of 4 was reflected in option C that was chosen by preservice science teachers. Table 4 in Appendix D demonstrates the indicators of the proficiency levels of each of the questions. Question #13 is identical, in relation to proficiency level 4, to that of question #1. Option C was chosen by preservice science teachers as the most suitable option to apply to the instructional scenario that has been provided in the question and is considered proficiency level 4. In addition, option D was not a suitable choice to the instructional scenario presented in question 1 and was considered proficiency level 1. Based on the 103 preservice science teachers' responses, the thresholds of the 4 proficiency levels for the 17 questions on the TPACK-P questionnaire were identified.

In the Taiwanese study that was done during 2015 by Jen *et al.* (2016), a total of 52 preservice and 47 in-service high school science teachers were used. During their data analysis of the questionnaires a similar trend was found as that of the preservice science teachers in this study. For their question 1 option C had the highest threshold demonstrating that this specific option was chosen as the most important consideration in the context provided in the item scenario. For most of their 17 questions, option D or level 1 was not selected as an important consideration by any respondent.

4.4 Locating the thresholds of proficiency levels on the scales.

The PMC and the responses given by the 103 preservice science teachers were used to locate the item thresholds on a scale as demonstrated in Figure 4.1. The thresholds of levels for all 17 questions on the knowledge about TPACK-P scale are listed in Table 4.1. By averaging the thresholds across the items, the thresholds of proficiency levels were located for the dimension of knowledge about TPACK-P as -3.00, -1.47, -0.42, and 0.49 (*logit).* Logit is a metric system used within the application of the IRT. Ludlow and Haley (1995) defined logits as the "interval level units of measurement corresponding to the total scores that have undergone an exponential transformation" (p. 969). They are defined as the "natural log of odds-ratio" (Ludlow, Hayley and Gans, 1992, p. 68).

As previously explained, by averaging the thresholds across items, the thresholds of proficiency levels were located for the dimension of knowledge about TPACK-P as -3.00, -1.47, -0.42 and 0.49 (logit). For level 1 the mean response was calculated as −3.00. By taking the mean score of each of the questions 1–17 and adding them together, the researcher will get a total score of −51.06. The researcher then takes the −51.063 and divides it through the total of 17 (for questions) and a mean score of −3.00 was established. The same method was followed with that of proficiency level 2, 3 and 4.

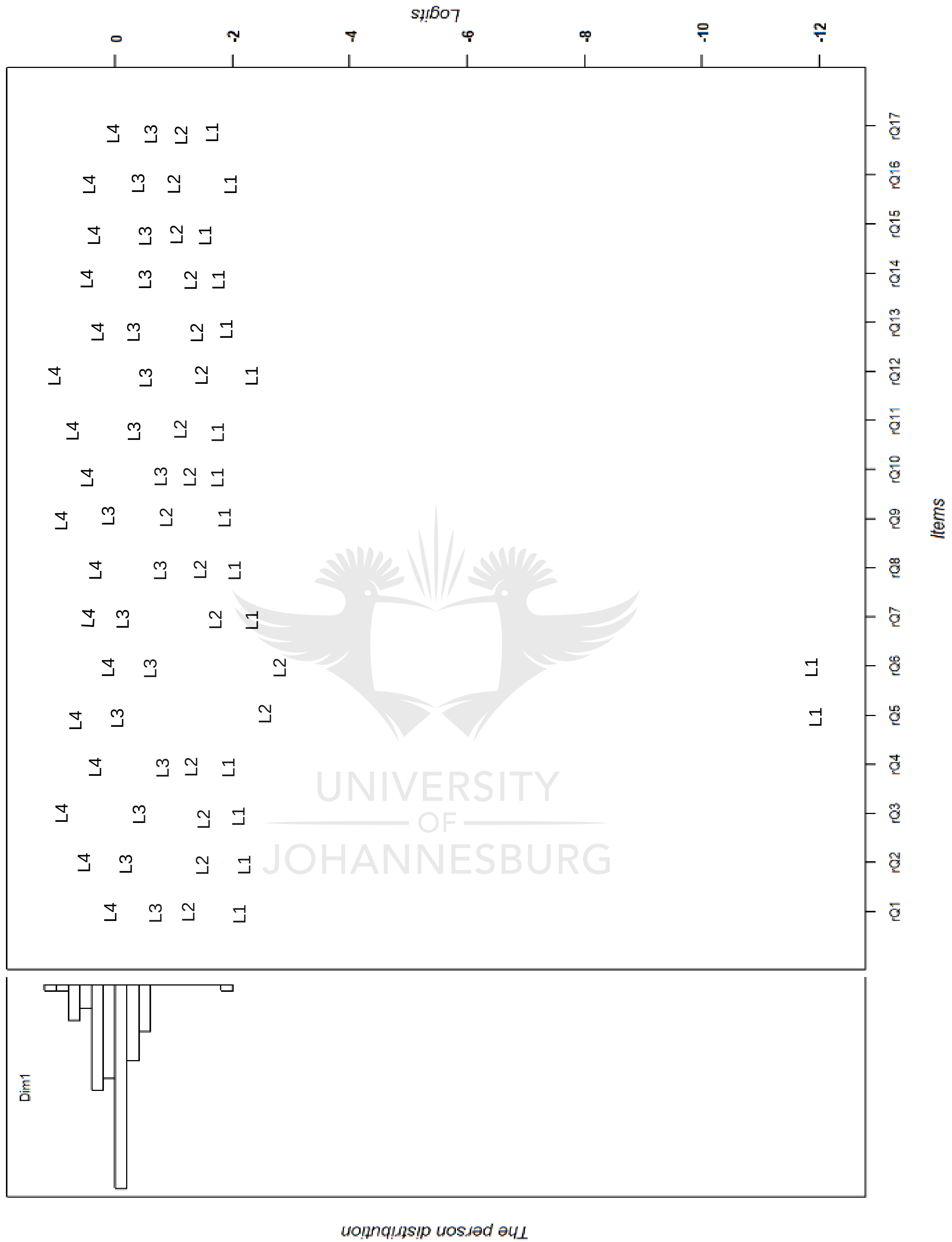

Figure 4.1: Item thresholds in Wright Map

4.5 Item infit and outfit statistics

First, the mean-square statistics were used to evaluate the validity of our assessment. Two fit-indices were reviewed: information-weighted mean-square (infit MNSQ) and unweighted mean-square (outfit MNSQ). The two fit-indices have different foci: while outfit is more sensitive to unexpected observations by persons on items that are relatively very easy or very hard for the subjects, infit is more sensitive to unexpected patterns of observations by items roughly targeted to them (Smith, Schumacker, & Busch, 1995). “Whereas the infit statistics deals with overall performance of an item, the outfit statistics are used to analyse if the responses are irregular and sensitive to outliers” (David et al*.,* 2018, p. 81).

These indices “represent the differences between the Rasch model’s theoretical expectation of the item performance and the performance actually encountered for that item in the data matrix” (Bond & Fox, 2015, p. 57). The MNSQ-values of the items should be close to 1. Linacre (2002) explained that thresholds used for these statistics are 0.5 to 1.5, with 1 being the ideal value. For example, while the MNSQ-values is greater than one, the observed item characteristics curve (ICC) is flatter than the expected ICC. That is, this “flatter” means that the estimating abilities in each level are closer and shows that the data is less predictable than the model expects. Therefore, the suggestion range of the MNSQ for a productive measurement is from 0.5 to 1.5 (Wu, Tam, & Jen, 2016).

Table 4.1 shows item measures and fit statistics. Excluding the no responses in level 0, the proficiency level 1 in item 5 and item 6 should not be considered to analyse the fit statistics. The fit statistics for the proficiency level 1 in the items 5 and 6 could not be estimated. The values for item 5 and item 6 are not available to use in the analysis of the fit statistics, due to a respondent that was scored 0 in the item. Using Q1 Category 4 in Table 4.1, the outfit value was 0.001 and infit value was 0.999. If these two values are added together, infit and outfit MNSQ will be equal to 1. For all 17 questions, the infit and outfit MNSQ were equal to 1.00, and the *t*-values were located in between −1.96 and 1.96. The *t*-values can be found in column 3 and 6 in Table 4.2 below. The results suggested that the equal discrimination assumption (with the expected ICC) was sustained (Bond & Fox, 2015; Jen, Yeh, Hsu, Wu, & Chen, 2016).

Therefore, the proposed PCM was used to interpret the participants' responses on this TPACK instrument.

Table 4.1: Information-weighted fit (infit) for the thresholds of item steps

Parameter	Outfit	Outfit_t	Outfit_p	Infit	Infit_t	Infit_p
Q1_Cat1	1	0,328	0,743	1	0,328	0,743
Q1_Cat2	1	0,124	0,901	1	0,124	0,901
Q1_Cat3	1	0,053	0,957	1	0,053	0,957
Q1_Cat4	1	0,001	0,999	1	0,001	0,999
Q2_Cat1	1	0,328	0,743	1	0,328	0,743
Q2_Cat2	1	0,157	0,875	1	0,157	0,875
Q2_Cat3	1	0,007	0,994	1	0,007	0,994
Q2_Cat4	1	0,029	0,977	1	0,029	0,977
Q3_Cat1	1	0,328	0,743	1	0,328	0,743
Q3_Cat2	1	0,184	0,854	1	0,184	0,854
Q3_Cat3	1	0,018	0,986	1	0,018	0,986
Q3_Cat4	1	0,051	0,959	1	0,051	0,959
Q4_Cat1	1	0,328	0,743	1	0,328	0,743
Q4_Cat2	1	0,157	0,875	1	0,157	0,875
Q4_Cat3	1	0,079	0,937	1	0,079	0,937
Q4_Cat4	1	0,018	0,986	1	0,018	0,986
Q5_Cat1	0	NaN	NaN	0	NaN	NaN
Q5_Cat2	1	0,157	0,875	1	0,157	0,875
Q5_Cat3	1	0,007	0,994	1	0,007	0,994
Q5_Cat4	1	0,041	0,967	1	0,041	0,967
Q6_Cat1	0	NaN	NaN	0	NaN	NaN
Q6_Cat2	1	0,229	0,819	1	0,229	0,819
Q6_Cat3	1	0,03	0,976	1	0,03	0,976
Q6_Cat4	1	0,012	0,99	1	0,012	0,99
Q7_Cat1	1	0,328	0,743	1	0,328	0,743
Q7_Cat2	1	0,157	0,875	1	0,157	0,875
Q7_Cat3	1	0,002	0,998	1	0,002	0,998
Q7_Cat4	1	0,025	0,98	1	0,025	0,98
Q8_Cat1	1	0,328	0,743	1	0,328	0,743
Q8_Cat2	1	0,157	0,875	1	0,157	0,875
Q8_Cat3	1	0,051	0,959	1	0,051	0,959
Q8_Cat4	1	0,014	0,989	1	0,014	0,989
Q9_Cat1	1	0,184	0,854	1	0,184	0,854
Q9_Cat2	1	0,056	0,955	1	0,056	0,955
Q9_Cat3	1	0,01	0,992	1	0,01	0,992
Q9_Cat4	1	0,056	0,955	1	0,056	0,955

Parameter	Outfit	Outfit_t	Outfit_p	Infit	Infit_t	Infit_p
Q10_Cat1	1	0,229	0,819	1	0,229	0,819
Q10_Cat2	1	0,184	0,854	1	0,184	0,854
Q10_Cat3	1	0,07	0,944	1	0,07	0,944
Q10_Cat4	1	0,019	0,985	1	0,019	0,985
Q11_Cat1	1	0,229	0,819	1	0,229	0,819
Q11_Cat2	1	0,124	0,901	1	0,124	0,901
Q11_Cat3	1	0,019	0,985	1	0,019	0,985
Q11_Cat4	1	0,034	0,973	1	0,034	0,973
Q12_Cat1	1	0,328	0,743	1	0,328	0,743
Q12_Cat2	1	0,113	0,91	1	0,113	0,91
Q12_Cat3	1	0,024	0,981	1	0,024	0,981
Q12_Cat4	1	0,048	0,961	1	0,048	0,961
Q13_Cat1	1	0,229	0,819	1	0,229	0,819
Q13_Cat2	1	0,124	0,901	1	0,124	0,901
Q13_Cat3	1	0,008	0,993	1	0,008	0,993
Q13_Cat4	1	0,011	0,991	1	0,011	0,991
Q14_Cat1	1	0,229	0,819	1	0,229	0,819
Q14_Cat2	1	0,157	0,875	1	0,157	0,875
Q14_Cat3	1	0,046	0,963	1	0,046	0,963
Q14_Cat4	1	0,022	0,982	1	0,022	0,982
Q15_Cat1	1	0,157	0,875	1	0,157	0,875
Q15_Cat2	1	0,089	0,929	1	0,089	0,929
Q15_Cat3	1	0,034	0,973	1	0,034	0,973
Q15_Cat4	1	0,019	0,985	1	0,019	0,985
Q16_Cat1	1	0,229	0,819	1	0,229	0,819
Q16_Cat2	1	0,079	0,937	1	0,079	0,937
Q16_Cat3	1	0,024	0,981	1	0,024	0,981
Q16_Cat4	1	0,027	0,979	1	0,027	0,979
Q17_Cat1	1	0,184	0,854	1	0,184	0,854
Q17_Cat2	1	0,138	0,89	1	0,138	0,89
Q17_Cat3	1	0,029	0,977	1	0,029	0,977
Q17_Cat4	1	0,003	0,997	1	0,003	0,997

4.6 Reliability

In this study, the competences were estimated as weighted maximum likelihood estimates (Warm, 1989). Because the test scores of zero and perfect scores can be computed, WLE is a preferred ability estimate for individual preservice science teachers (Linacre, 2009). A perfect score in this study would mean a score of 4 for an item, that links back to proficiency level 4. To estimate item and person parameters, a scoring of 0.5 points for each category of the testing items were applied. Table 6 (in Appendix E) shows the person parameters of WLE estimates and its reliabilities for all persons. As Table 6 (Appendix E) shows that the subject's abilities about TPACK-P were ranging from -1.94 to 1.14. in addition, the WLE reliability for these 17 items was 0.51 and Cronbach's α was 0.60. The reliability values were acceptable but not good.

4.7 Distribution of preservice science teachers

With item difficulties there are thresholds of the different proficiency levels. According to the means established for each proficiency level in Table 4.2, the preservice science teachers' WLE between -3.00 and -1.47, places them on level 1, between -1.47 and -0.42 places them on level 2, between -0.42 and 0.50 places preservice science teachers on level 3 and from 0.50 and higher places preservice science teachers on the highest proficiency level of 4. In Table 6, the column of WLE was used to determine the student's proficiency level on TPACK-P.

The paragraph demonstrates the following: According to the means that were established, preservice science teachers WLE, in Table 6 (Appendix E) that was between -3.00 and -1.47 was located at proficiency level 1. Preservice science teachers with means between –1.47 and –0.42 was located at proficiency level 2. Means between -0.42 and 0.50 was located at proficiency level 3 and means that was higher than 0.50 was located at level 4. In table 6, the reader needs to focus on the 5th column that demonstrates the WLE calculated for student 1. That WLE will establish in what proficiency level the student falls. The preservice science teachers mean was taken within the different levels and added up and divided through the number of preservice science teachers that chose a specific option on the questionnaire. If we consider question #1, option C was allocated proficiency level 4. The mean for this option was 0.012. Option D was allocated proficiency level 1. The mean for this option was -2.009. These means, otherwise known as thresholds, have been used to draw the WrightMap to establish the preservice science teachers' proficiency on the knowledge of TPACK-P.

Table 4.2: Thresholds of item steps for the questions in TPACK-P

Item no.	Level 1	Level 2	Level 3	Level 4
Q1	-2,0094	-1,1990	-0,7310	0,0129
Q2	-2,1296	-1,7165	-0,1302	0,5212
Q3	-2,0159	-1,7359	-0,3811	1,0555
Q4	-1,7901	-1,3136	-1,0207	0,4497
Q5	-11,9999	-2,6163	0,1335	0,7127
Q6	-11,9999	-2,7159	-0,5582	0,2511
Q7	-2,1567	-1,7511	-0,0337	0,4388
Q8	-1,8809	-1,4039	-0,7907	0,3078
Q9	-1,9615	-0,8943	0,1667	0,9161
Q10	-1,3642	-1,2646	-0,9282	0,4781
Q11	-1,7079	-1,3217	-0,3496	0,6763
Q12	-2,2436	-1,3907	-0,4543	1,0247
Q13	-1,7472	-1,3569	-0,1319	0,1806
Q14	-1,4858	-1,2854	-0,7222	0,5054
Q15	-1,2926	-0,9066	-0,4743	0,3838
Q16	-1,9454	-0,9742	-0,3719	0,5228
Q17	-1,3320	-1,1732	-0,4236	0,0570
Mean =	-3,0037	-1,4718	-0,4236	0,4997
SD =	3,3985	0,5171	0,34850	0,3050
SE =	0,1999	0,03042	0,0205	0,0179

4.8 Discussion

A 17-item questionnaire was used to collect data on the proficiency level of science preservice science teachers on TPACK-P. These 17 items set out different instructional scenarios on science teachers' implementation of ICTs in instruction. Each item has four options that individually represent typical performances that teachers at levels 1 to 4 display. Level 4 (reflective application) is the highest proficiency level and it indicates that they are adept at using their experienced-based TPACK to employ ICTs in assisting their learners in learning about science. Level 3 (infusive application) used ICTs to guide students to self-explore and independently construct their science knowledge. Level 2 (simple adoption) used ICTs to help learners learn about science via more teacher-centred strategies or with less well-founded rationales. Level 1 represents the teachers that only have a basic understanding of technology, resulting from their limited experience (or lack thereof), negative impressions regarding technology in the classroom, or a lack of intention to implement ICTs in their classroom.

These 17 items were presented to preservice science teachers to evaluate their knowledge on TPACK-P. A WLE score for each of the participants would mean a higher level of understanding of TPACK-P. A lower raw score would mean a lower level of understanding of TPACK-P. When we use Rasch analysis on this data, (with the coding) higher number is an indication of a higher level of proficiency, thus a good knowledge on TPACK-P. If we consider the results that were achieved during this study Table 4.3 demonstrates the distribution of the science preservice science teachers on the different proficiency levels of TPACK-P, that was established using the thresholds.

Considering the person's WLE that were established during Rasch analysis, the thresholds were established for each proficiency level. Table 4.3 demonstrates the distribution of preservice science teachers on the different proficiency levels of TPACK-P

Table 4.3: Distribution of preservice science teachers on different proficiency levels of TPACK-P

Proficiency level	Preservice science teachers
Level 1	0.99%
Level 2	6.79%
Level 3	82.52%
Level 4	9.70%

As demonstrated by Table 4.3, 82.52% of preservice science teachers have a proficiency level 3 for their knowledge on TPACK-P. A proficiency level of 3 demonstrates the infusive application, where the teacher makes use of ICTs to guide learners to self-explore and independently construct their science knowledge. Only 9.70% of the preservice science teachers were located at level 4 where they are adept at using their experience-based TPACK to employ ICTs in assisting their learners in learning science. Considering the great number of preservice science teachers found on level 3 proficiency of TPACK-P, knowledge of TPACK-P by these preservice science teachers is quite high.

4.8.1 Illustrative cases of TPACK-P proficiency

TPACK-P is a very important attribute science teachers must have to allow abstract science concepts to become more understandable to learners. In the previous paragraphs I have discussed the results of the quantitative research that was done during the study. In the following paragraphs I am going to illustrate the different proficiency levels of the students in the study and how they understand the implementation of TPACK-P within the science classroom. The five preservice science teachers were purposefully selected for the interviews, because of the proficiency level they achieved during the quantitative research. For the interview, preservice science teachers were providing their names, but they will remain anonymously and are provided with numbers during this discussion. Many of the interviewees were located on level 3 proficiency level of TPACK-P. Preservice science teachers do not always agree with each other about the implementation of TPACK-P in the classroom and therefore they will choose different outcomes on the instructional scenarios that were provided to them in the questionnaire. It was also discovered that with some of the instructional scenarios that were provided to the preservice science teachers, an agreement was reached to use the same technological implementation in the classroom. The proficiency of the preservice science teachers TPACK-P will be demonstrated below, using the three main knowledge domains as guidelines. The students had to complete a questionnaire to determine their TPACK-P proficiency level, and 10 were selected to participate in the interviews. As explained in the chapter 3, due to availability and schedules, only five preservice science teachers attended the interviews. z

4.8.2 Assessment knowledge domain

Assessment plays a very important role in assessing how learners use multiple techniques to construct their own knowledge (Yeh et al. 2015). Various forms of assessments can take place in the classroom whether it is informal or formal assessment. The student had various opinions during the interview about assessing learners during a lesson. The headings in the following section come from A Table 3.2 of the Item indicators on page 43.

A. The use of videos and animations to understand student learning

The use of videos and animations helps the preservice science teachers to understand how student learning takes place. Student 1 explained that videos and animations help them to assess students' content comprehension through dynamic presentations. This represents proficiency level 3 of TPACK-P. Student 1 stated that *"videos and animations provide learners with a visual presentation of abstract concepts that is difficult to demonstrate in the classroom. It further allows me as the teacher to assess learner's comprehension based on the manipulation of simulations, responses to questions that I ask as well as questions that they would ask me about content."* The manipulation of simulation therefore allows teachers to understand what learners understand of the content she teaches in the classroom. Student 33 differed from student 1, by explaining that the use of videos and animations helped him elicit students' prior knowledge and/or misconceptions. This choice represents proficiency level 4 of TPACK-P. These proficiency levels of the students were also coded by STATCON to ensure that the results will be reliable, and this applies to all the qualitative results in this study. Student 33 stated that *"when I play a video first before the lesson, it assists me as a teacher to see what my students' do not understand. The video plays a role to help them remember some of the stuff they forgot."* The teacher can therefore see what the students' understanding is on the content and therefore showing them the video helps him to understand what the learners know and do not know. These videos also allow them to demonstrate their prior knowledge on the concepts.

B. Use of simulations to identify learning difficulties

Various teachers also use simulations to assess learners' understanding on the practical component of science. The simulations also allow teachers to identify the various learning difficulties that learners might experience in the science classroom. Student 72 explained that the simulations help him to identify preservice science teachers learning difficulties, because they help him to observe the difficulties students face from their simulation manipulations. The student stated that *"simulations are real hands on motivators for learning empowering. Simulations are cheaper than real life* *experiments or events including field trips, making simulations more useable. It is also an imitation of concepts and processes of Life Sciences."* This explanation demonstrates proficiency level 2 of TPACK-P. Student 33 agrees that they can identify students' learning difficulties because they help them to observe the difficulties preservice science teachers face from their simulation manipulations and states that *"simulations make small things to be bigger and bigger things to be on average scale, like the universe. When giving them PhET and ask them to manipulate it, it will help me to see whether they understand the concept I am teaching or not."*

C. Usefulness of technology integration in helping learners with different learning styles/needs

Considering that simulations can help with the identification of different learning difficulties, learners also differ when students have different learning styles and needs. Technology integration in the classroom can therefore be useful in helping students who have different learning styles or needs. Student 1 explained that technology integration can present difficult subject content in diverse and efficient ways for students to understand. She stated that:

"According to Gardener's theory of learning, all leaners have different styles of learning. Technology presents the opportunity to diversify learning as content can be presented to suit different learning styles. For example, podcasts or songs will appeal to learners who have musical intelligence and videos and simulations will appeal to those who have spatial intelligence. Programs that provide virtual classrooms also allows for collaboration between learners and tools of assessment (such as online quizzes) allow for impersonal learning."

With different learning styles, teachers need different teaching methods to ensure all learner needs are catered for in the classroom. Learners all learn differently, and the same method can be used. Teachers cannot expect all the learners to perform the same if just one teaching method is used. Student 72 explained that teachers can use technology integration to adaptively assess students' knowledge and then offer instruction based on assessment. She stated that *"technology is important in classroom because it opens up different ways of communication in our modern world. Technology can take the student from this class to a huge wealth of resource of* *learning community."* Therefore, assessing the student first and seeing how they do on the assessment, teachers can adapt their teaching in relation to the assessment, to ensure the learners will understand the content.

D. Understanding of technology-supported assessments

Considering the different assessments that can be used by teachers in the classroom, different understandings of what technology-supported assessments are can be used by teachers. Student 1 explained that multimedia assessments allow for evaluations of various aspects of learning in ways that exceed limited conventional assessments. She stated that:

"*Technology can be used to assess skills and knowledge that is difficult to assess through conventional pen-and-paper methods, especially in schools that lack the necessary resources. For example, simulations can be used to assess certain lab skills and investigations can be carried out where no physical lab equipment is available. Multimedia assessments is also time-efficient and provides real time feedback to both preservice science teachers and teachers which they can reflect on to improve learning*."

Student 33 agreed and stated that *"using different assessments strategies help check whether learning took place in different ways."*

E. Distinctive features of technology-supported assessments

Technology-supported assessments have several distinct features that differs from conventional assessments. Student 47 chose the feature that they offer instant feedback and preliminary score analyses. She explained that:

"Using multiple choice test for example it gives learners feedback on their performance and as the assessor you get an indication of problem areas in a form of a graph showing percentage of every question performance or average."

This is proficiency level 2. Student 1 opposed student 47. Student 1 was choosing an instructional scenario of proficiency level 1. Student 1 shows that there are no major differences in terms of item content; key difference is in the interfaces they use to present information. She stated that:

"*Both technology-supported assessments and conventional assessments can be used to assess the same content. However, the presentation of these assessments is vastly different. For example, technology-supported assessment provides instant feedback and thus allows the teacher to immediately identify and address misconceptions. It is time-effective and in some cases allows learners to be assesses in concepts that is not possible to assess through conventional methods. For example, learners can perform investigations using simulations where there are no physical resources available or when the topic of investigation involves abstract concepts that cannot be physically manipulated. It also allows learners to easily collaborate in group/ peer assessment tasks (e.g. communication tools, virtual classrooms, conducting online interviews etc.). Technological interferences also seem to appeal learners better than conventional presentations*."

4.8.3 Planning and designing knowledge domain

A. Teachers learning subject content using technology

When we look at the planning and design domain we mainly refer to the practices teachers use to plan their lesson, keeping in mind the use of ICTs, different teaching techniques and the knowledge that is demanded from the topic by the learners. Even teachers can learn more about their subject content using technology. Student 47 explained that teachers can attend workshops or make use of online resources to keep updated. She stated that *"there are seminars, workshops for provincial, nationwide, district or specialisation all to inform and enrich teachers and keep them on par with what is current locally or with the rest of the world"*. As teachers, we have many workshops available to help us keep updated with new teaching methods but also new technology that we can make use of in the classroom. These workshops are coordinated by the education district offices or even companies such Pearson to develop teachers technologically and provide help wherever they need help. Student 1 agreed that workshops and online resources can keep teachers updated. She stated that *"the internet provides almost unlimited access to a variety of resources that will enable them to learn more about the subject content. This includes online workshops, webinars, video simulations, animations, images, websites explaining and e-textbooks."*

Student 33 did not agree and explained that teachers can learn more abstract concepts by using different technology functions (like multiple representations, slow motion displays). He stated that *"YouTube is the best teacher to teach teachers about technology".* This statement displays the proficiency level 4 of TPACK-P knowledge while the two previous preservice science teachers displayed proficiency level 2 with their knowledge. Student 72 supported student 33 and explained that *"teachers also do have misconceptions/ misunderstandings or difficulties in making the concepts more meaningful to the learners, by using technology, teachers can gain more understanding of abstract concepts".* Considering the statement made by student 72, teachers also have misconceptions when it comes to certain abstract concepts and their misconceptions can be carried over to the learners when these abstract concepts are being explained. With the use of technology, these misconceptions that are held by the teacher and the learners can be cleared up and a better understanding of what the abstract concept entails can be explained to teachers and learners. Abstract concepts are difficult concepts to explain to learners when they cannot physically visualise the concept in front of them. Technology provided a solution to this problem by allowing videos, animations and various simulations to be shown to learners allowing them to create a better understanding of the concept.

B. Types of subject content suited for technology-supported instruction

Considering that teachers can learn their own subject content better with technology, several types of subject content are suited to teach with technology-supported instruction. Student 47 explained that units that require student motivation to learn are suited to use technology-supported instruction. She stated that *"content that is daunting and rather involved learners need the extra push or content is needed to make accessible using technology-supported instruction."* This displays a proficiency level of 2. Preservice science teachers did not agree on this concept. Student 1 explained that abstract concepts that are difficult to present in conventional instruction will be better suited for technology-supported instruction. This displays the proficiency of level 3 on the knowledge of TPACK-P. She stated that:

"*It is possible to support units that require preservice science teachers' motivation as well as concepts that can be learnt through manipulating simulations with technology. However, it is especially useful to present abstract concepts that are difficult to present* *in conventional instruction as it can provide visual representation of the concept to enhance preservice science teachers' understanding. For example, learners may understand the concept of electromagnetic waves better if they are able to actually see the wave behaviour and properties in pictures or simulations."*

If we consider the explanation provided by the student, her understanding is more of proficiency level 4 than that of 3 because of her use of simulations. Students 33, 53 and 72 are all in agreement that the types of subject content that are suited to teach with technology-supported instruction are concepts that need preservice science teachers to learn from manipulating simulations or doing experiments. This choice demonstrates proficiency level 4. Student 33 stated that *"Physical Science and Life Sciences are suitable to use PhET and Mathematics, it is suitable because there are apps like GeoGebra that you can use as a teacher. Therefore, it is topic specific, it depends on the topic and the nature of your school."* For teachers there are several websites or even applications that can be used to demonstrate content to learners. Learners find it difficult to grasp content that is not physically available to them to see or even to take apart to see the different layers, for example the human body. Applications can take the different layers of skin, tissue and fat away to demonstrate the skeleton to the learners.

C. Factors influencing teacher's planning and designing

When thinking about the best subject content suited to be taught with technology-supported instruction, teachers also must think about different factors that influence their planning and designing of technology-supported instruction. Students 1 and 53 agreed that factors such as the improved visual effects of graphic designs and concept presentations influence teacher's planning and designing. Student 1 stated that *"the improved visual effects grab learners' attention and motivates them to participate in the lessons as well as enhances their understanding of concepts that are visually represented during presentations."* If teachers use different visual effects such as animations during lessons, learners will be more eager to learn and concentrate during a lesson. Student 53 stated that *"the change in technology affect teachers because they also have to keep on learning."* Not all teachers are eager enough to learn about the use of technology in their classroom. We have seen in the literature review that teachers' fear of change is a negative aspect in the implementation of technology because they must attend different courses to learn about the use of technology, but other teachers will seize the opportunity to learn new teaching methods with the use of technology and see it as an opportunity to improve their lessons.

Student 47 explained that the factor of increased efficiency of teacher instruction influences teachers planning and designing. She stated that *“if a teacher is comfortable with using the technology, and is able to manipulate it, it is more likely they will incorporate it into the lesson planning and design.”* If a teacher is comfortable in using simulations and different applications that demonstrate and explain the work efficiently, they will include it in their lesson planning and follow through with it. Student 33 disagreed with the other preservice science teachers. He explains that the factors of student learning motivations and responses influences a teacher’s planning and designing. He stated that *“the topic plays a role in whether I have enough material for students’, if I prefer to use chalk. Also, time and curriculum coverage play a role. I cannot be fancy and use software, if I am chasing time to finish the curriculum.”* Time and curriculum coverage can influence teachers planning and designing when it comes to technology-supported instruction. If time is limited, a teacher might not use the different applications and simulations to explain different concepts to learners. They will explain the important concepts and try and finish the curriculum on time.

D. Instructional objectives appropriate for technology-supported instruction

As several factors influence teachers’ planning and designing of technology-supported instruction, teachers also must consider the instructional objectives they want to achieve when they implement technology-supported instruction. One of the instructional objectives student 47 chose was the enhancement of teachers’ instructional efficiency and the improvement of learners’ comprehension and thinking abilities, a proficiency level of 4. She stated that *“to enhance instructional efficiency simply meaning to make the instructions easier to understand with the help of technology, learners will not need to do much. With regard to comprehension and thinking abilities with technology we are forever wanting to know more and find out more.”* Considering the statement of the student, teachers need to make sure that instructions within the classroom are on the level of the learners, where they will understand what to do in any assignment, task or activity done in the classroom.

Technology plays a role, because teachers can demonstrate to learners what needs to be done in increasing their understanding but also their excitement as tasks, assignments and activities done become easier.

Students 33 and 53 also chose the same instructional objectives as student 47. Student 33 stated that *“technology must be used to enhance preservice science teachers understanding but a teacher needs to be trained to use effectively.”* Teacher training is a necessity when it comes to the implementation of technology in the classroom. If a teacher is not trained probably, the use of technology becomes difficult and this can demotivate teachers. Student 53, on the other hand, explained that *“technology does not only help learn content knowledge but their comprehension at large and their reasoning.”* Student 1 explained that the instructional objectives that are appropriate for technology-supported instructions are the objectives that help learners form a better understanding of the course content and clarification of key concepts. This demonstrates a proficiency level of 3. She stated that:

“Technology can be used to support instruction, not replace it. Therefore, the main objective should be to enhance understanding of concepts taught, especially abstract concepts that are difficult to teach and misconceptions that ought to be addressed. However, learner motivation and instructional efficiency can also be lesser objectives of technology-supported instruction as they also play an important role in the classroom.”

Considering the explanation above, technology can never replace all teaching methods in the science classroom. Demonstrations, models and practical investigations will always be part of science. Technology can be used to support these different teaching methods to allow learners to understand difficult concepts better.

E. Appropriate technological tools for content presentation

Technological tools play a significant role in teachers developing content and presenting the content, whether it is the use of PowerPoint slides, animations or even simulations. Student 1 indicated that the appropriate technological tools will depend upon how explicitly technology presents subject content and how helpful it is in guiding preservice science teachers to think scientifically. She stated that *“the tools chosen to support instruction must be relevant to the content and serve to enhance learning and* *guide student's thinking instead of creating confusion or misconceptions. Therefore, the selection of the tool depends on the context of the classroom, learner strengths and the nature of the content taught."* A teacher needs to choose the appropriate tools to allow proper instruction. If a colour change needs to be taught to learners, a teacher can demonstrate the practical to learners or even show them a video. Student 33 agreed on the same technological tools and explained that *"other topics will require me to use videos for them to understand better but do not. So, it depends which topic I am teaching and whether technology will assist to achieve my goals or not. If I am using a video in class I either play it before the lesson or after, this depends on the nature of the topic."* This is a demonstration of proficiency level 3.

Student 47 displayed a proficiency level of 4 by choosing the technological tools of based on preservice science teachers' prior knowledge, instructional procedures and subject concepts. She explained that "*it does not make sense to use something that learners are not familiar with to teach them so starting with the basics of what they know is making a concept accessible to them, gradually you can move to a different tool*." If a student does not understand the work or the prior knowledge is that of misconceptions, bringing in a new technological tool to teach new concepts can confuse learners. The teachers need to teach the concept in such a way that learners will understand it and then afterwards use new technology such as that of simulations to show learners new concepts.

Student 53 and 72 disagreed with the preservice science teachers above. Student 53 chose the technological tools that depend on the availability of resources such as animation, images and PowerPoint. She explained that a *"teacher has to use what he or she has to enhance teaching and learning so whatever is available will be used."* Here the student explains that teacher must use the resources available to teach different concepts to themselves, whether it is the use of PowerPoint, displaying images or even showing videos to learners. This displays a proficiency level of 2. Student 72 only displayed a proficiency level of 1 with his choice of technological tools. He explained that presenting textbook content in PowerPoint satisfied his instructional needs. He also stated that "*technology tools depend on the availability of resources. The use of technology tools that will fit the topic and technology tools that will be available to present a certain topic*."

F. Selection and use of teaching strategies to assist technology-supported instruction

Even though teachers have the appropriate technological tools to present content in their classroom, different teaching strategies need to be selected to assist technology-supported instruction. Student 47 uses teaching strategies that engage preservice science teachers in group collaboration to promote their comprehension. She explained that *"when engaging in groups, there are multiple personalities that do not learn the same it is highly likely they will state what they prefer, and one has to pair that with a suitable technology-supported instruction".* Student 33 supported this teaching strategy and explained that *"I select different items from the internet for preservice science teachers to do presentations about their selected choice. This help them to work in groups and learn to work with different people not their friends always."* This demonstrates a proficiency level of 3.

Student 1 chose the teaching strategy of questioning strategy or asking preservice science teachers to draw from their impressions to help them identify key concepts, demonstrating a proficiency level of 2. She explained that:

"I usually ask guided questions based on what the learners have observed from videos or simulations. Learners form their own conclusions regarding concepts on their own or in group collaboration. I do not often use technology for inquiry and self-learning as it is often time-consuming and difficult to ensure that what learners explore is aligned to curriculum standards and requirements."

Student 53 did not choose a wide variety of teaching strategies and explained that teaching with technology already accommodates her instructional needs, no other instructional strategies being required. She also stated that *"a lesson can be taught using technology because it can be used differently".* She displays a proficiency level of 1 where she only has a basic understanding of technology-supported instruction in the classroom.

G. Effects of group collaboration coupled with technology-supported instruction

Group collaboration helps learners to work together and understand concepts better than individual activities. All five preservice science teachers agreed on the same effects of group collaboration joined with technology-supported instruction. All five preservice science teachers felt that a technology-supported environment can be developed that accommodates students' collaborative completion of tasks, but personal learning outcomes should be carefully considered. Student 47 explained that *"in collaborative work it is likely other learners work more than others and other learners' efforts are not evident in completion of tasks. Therefore, as an individual, learning outcomes are not met especially if they did not contribute."* Student 33 supported the statement given by student 47 and stated that *"if learners are working in groups some of them might not participate and this will create a thought that they all understand. That is why it is important to have individual outcomes too".*

Student 1 explained that:

"Group collaboration can be supported by technology to present course content as well as to improve learner motivation. However, learners learning style and pace as well as strengths and weaknesses need to be considered. Their personal outcomes that come with individual learning (as learners are ultimately assessed individually in formal exams) must be considered so that the situation of a single learner doing all the work while his/her peers watch is avoided. It must be ensured that the technology-supported environment allows all learners an equal opportunity to participate in activities so that all learners grasp concepts taught."

Student 72 explained that *"technology-supported environment that accommodates student's collaborative completion of tasks can be developed, but personal learning outcomes should be carefully considered."* Considering the statements provided by the preservice science teachers, one factor that continuously comes up is a criticism of group work. One learner does all the work in the group and the rest of the learners receive the same mark even though they have done nothing. By adding the individual learning outcomes to the group collaborations will force all learners to work together and achieve the same marks.

4.8.4 Practical teaching domain

Practical teaching can be explained as the knowledge teachers have on the practical implementation of ICTs in the classroom.

A. Technology-supported instruction is considered special.

Compared to conventional instruction where teachers use the blackboard to teach or transparencies, technology-supported instruction is considered special. Technology-supported instruction allows teachers to make abstract concepts more understandable and visual to learners. Student 1, student 33 and student 53 all agree that technology-supported instruction helps abstract concepts and related examples to be concretely visualised in less time. A demonstration of proficiency level 4. Student 1 explained that:

"If used effectively, the use of the appropriate technological tools enhances learner understanding in ways that the teacher cannot, especially for abstract concepts that are not easily represented. For example, a simulation or animations can be used to explain models of the atom. It is particularly effective when concepts involve movement, for example in the motion of electrons around the nucleus, as this is better explained visually instead of orally."

Student 33 explained that *"it should be considered because it helps learners to be interested and understand science better as they are able to visualise the small things like atom".* Student 53 explained that *"abstract concepts are visualised and made less abstract and easier to understand".*

B. Opinions regarding synchronous communication tools and their relation to asynchronous communication tools

Student 1 explained that synchronous communication tools improve teacher-student interactions in non-classroom settings. She explained that:

"Synchronous communication tools improve communication outside of the classroom as it allows the opportunity for teachers and learners to interact in real time with immediate feedback. Learners can ask questions and the teacher (or other learners) can aid almost immediately. Information regarding course content, interesting findings, links to relevant websites can also be shared and announcements can be made before the next lesson. This is far more effective than only being able to communicate during class time."

This demonstrates a proficiency level of 3. The other preservice science teachers had difficulties in explaining what synchronous and asynchronous communication tools are and their opinions thereof.

C. Handling problems with technology-supported instruction

Teachers can face several problems with technology-supported instruction in the classroom. How they handle these problems depends on the teacher. Student 47 and student 1 agreed and explained that they would use previously prepared teaching materials, for example online or standalone versions. This displays a proficiency level of 4. Student 47 explained that *"it is easier to refer to previous encounters to see how to go about the problem if not solve it in the same way".* Student 1 explained that:

"This generally depends on the problem involves the tool I have chosen, I refer to teaching materials that I or a fellow teacher has prepared and made available online or a programme that has already been installed and is ready to use. However, if the problem arises from an internet or connectivity problem, I would refer to the blackboard and handmade materials, models or posters that I have available."

Problems with technology-supported instruction can arise quickly, such as power outages or even internet connection problems. Teachers must adapt quickly to problems that might arise and having a plan B is a must.

Student 33 disagreed and choose the chalk-and-talk instruction to handle his problems with technology-supported instruction. He explained that *"most of the township schools have smartboards that get broken. As teachers you are required to use the chalkboard again. Even if the blackboard is working, teachers still prefer the chalkboard because the smartboard is too slow."* This displays the proficiency level of 1. Student 53 explained that she handles problems by uploading learning materials online for student learning. She stated that *"uploading learning materials online helps to eliminate confusion in the future for preservice science teachers and instruction".* This displays a proficiency level of 3.

D. Opinions about applying technology to instruction management

Student 1 and student 33 agreed that curricula can become innovative and cross-disciplinary when digital educational resources are meaningfully and purposefully integrated. Student 1 stated that:

"Technology-supported instruction can/has the potential to greatly improve the quality of instruction in classrooms. However, there is a need for resources that specifically relate to the South African curriculum and context for this to be effective. At present, majority of the tools that I have interacted with seem to have been created with American curriculum in mind. It is difficult to find resources that relate to the South African classroom or examples that relate to the typical South African learner. The curriculum itself can be transformed to be more innovative and integrate technology-supported instruction with updated content relevant to South African society today so that more learners are exposed to technology that will support and enhance their learning."

This displays a proficiency level of 4.

Student 47 disagreed and explained that operating systems (like Microsoft) can be useful when organising teaching materials that have been collected over a long period of time. She stated that *"this is the simplest and I like to think the most traditional way to manage material. One won't need the internet and can access it easily from their technological tool."* This displays a proficiency level 2.

4.9 Conclusion

In this chapter the researched data was analysed and interpreted using Rasch analysis to address the research question of this study. The data analysis provided me with the necessary information to answer my research question as well as achieve the aims and objectives of this study. From the results of both the quantitative and qualitative studies we have done we can conclude that the preservice science teachers from the University of Johannesburg have a proficiency level of 3 in their knowledge of TPACK-P. The results that was achieved were on the same level of our counterparts in the Taiwanese study.

CHAPTER 5

DISCUSSION OF FINDINGS, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 Introduction

In the previous chapter the research data was analysed and interpreted to address the research question. This chapter will provide the discussion of the findings, the conclusion, the limitations as well as the recommendations for further studies will also be discussed.

5.2 Discussion

The aim of this study was to determine the proficiency level of preservice science teachers. To achieve the aim of the study, a literature review on the different knowledge domains that make up the TPACK-P framework, factors that influence teacher's implementation of ICT's, the benefits of implementing TPACK-P was conducted. An explanatory sequential mixed-method design was followed. During this design, quantitative data and qualitative data was collected. During the quantitative data, a 17-item questionnaire was administered to 200 preservice science teachers. The data was analysed using Rasch analysis. During the Rasch analysis the multidimensional PCM was used to produce a WrightMap. The WrightMap demonstrates the different thresholds for each of the 17 questions in the questionnaire. After the analysis it was established that 82.52% of the preservice science teachers have a proficiency level of 3 on their knowledge of TPACK-P. Proficiency level 3 demonstrated the infusive application, where the teacher makes use of ICTs to guide preservice science teachers to self-explore and independently construct their science knowledge. Only 9.70% of the preservice science teachers were at proficiency level 4. On proficiency level 4, preservice science teachers are adept at using their experienced-based TPACK to employ ICTs in assisting their learners in learning science. Considering the great number of preservice science teachers found on level 3 proficiency of TPACK-P, knowledge of TPACK-P of these preservice science teachers is on an adequate technological implementation level. After data was analysed and preservice science teachers were allocated their proficiency levels, five preservice science teachers were purposefully selected to be interviewed on their knowledge of TPACK-P. During the interviews the preservice science teachers provided a deeper understanding on the different instructional scenarios that were chosen by them on the questionnaire. During the interviews, the answers provided by the students allowed an understanding to be developed on their knowledge of TPACK-P. During the interviews it was apparent that a few of the preservice science teachers have a difficulty in understanding some of the terminology used and struggled to answer question asked. One of the difficult terminologies was the question on synchronous and a synchronous communication. Only student 1 was able to provide an understanding of how these types of communications helped to improve teacher-student interactions in the non-classroom setting. This involved use of emails and even sharing of websites to improve learner understanding. During the interviews the preservice teachers also provided an understanding on factors that influence the implementation of ICT in the classroom, whether it was a beneficial factor or an inhibiting factor. An inhibiting factor that came up is the issue of electricity provision. If the electricity is switched of, no ICTs can be used, and the teachers need to divert back to using the blackboards in the classroom. The answers provided by the students corresponded with the responses that they provided on the questionnaire. The following research question needed to be addressed:

What is the TPACK-P proficiency of preservice science teachers?

5.3 Conclusion

TPACK-P is a knowledge developed by teachers over a long period of time using their experiences in long-term planning and instruction using ICT to support their different teaching needs. With the roll-out of technology currently taking place in South Africa to enable teachers to effectively implement technology in the classroom, the development of TPACK-P is very important. To ensure teachers are well-developed in the implementation of technology in the classroom, tertiary institutions need to ensure that their teacher education programs include the embedding of ICT in the classroom. As we have seen in this research study, 82.52% of preservice science teachers at the University of Johannesburg demonstrated a proficiency level 3 for their knowledge on TPACK-P. There are still a small number of students that demonstrate a proficiency level of 1 and 2. Level 1 was at 0.99% of preservice science teachers and level 2 was at 6.79%. These two levels either demonstrate the preservice science teachers on a simple adoption level where teachers use ICTs to help the learners learn about science via more teacher-centred strategies or with less well-founded rationales, or teachers with a basic understanding of technology resulting from their limited experience in the implementation of ICTs in the classroom. The preservice students also demonstrated during the interviews their understanding of TPACK-P. The implementation thereof plays an important role as the new generation of learners coming through being are being brought up with technology freely available to them at home and even in the community itself.

Hennessy, Haßler and Hoffmann (2015) did a study that explores the “opportunities and challenges for supporting schoolteachers’ professional learning about interactive teaching and digital technology use in sub-Saharan Africa (SSA)” (p. 537). During this research the different factors that enable and constrain ICT implementation in the classroom were focused on. They explained that research evidence is limited on interactive teaching but there are indications that “supporting factors include modelling, classroom trailing, reflection and feedback” (Hennessy et al. 2015, p. 537). Considering these supporting factors, “access to technology equipment (and telecommunication) and developing technical skills can be a powerful source of teacher motivation for participation in PD, but our experience is that wanting to develop one’s own teaching practice can arise out of professional pride.” (p. 540). The factors mentioned here was also explained by these preservice students during their interviews as factors that needs to be considered when TPACK-P needs to be implemented and their understanding of TPACK-P.

5.4 Limitations of the study

This study was subjected to some limitations. Firstly, out of 200 preservice science teachers 97 did not complete the questionnaire for the study, limiting the numbers to 103 preservice science teachers. This could be due to the questionnaire not counting for marks towards the end of semester mark. Secondly, 10 preservice science teachers were purposefully selected for the interviews and only five attended the interviews, limiting the amount of data that was collected. The sample size of 3the study was relatively small at 103. and is not large enough to represent the entire population of ± 250 preservice science teachers at the university. The limitation to the administration of the questionnaire was the retrieval of the questionnaire. For the retrieval of the questionnaires, I had no control over it. A colleague collected the questionnaires the following week. Not all preservice science teachers handed in the questionnaire even after being reminded to do so. During the interviews as well, not all preservice science teachers attended the interviews and it was limited to only five. The preservice teachers are very reluctant to give up their spare time to help with any research if it does not contribute to their marks. A recommendation that I would make for future researchers is that preservice science teachers must answer the questionnaire in the classroom and hand it in as soon as they are done. A bigger sample of students needs to be considered to ensure more reliable data.

5.5 Implications for further research

Based on the findings of this research study, the following implications for further research are suggested. It would be interesting to investigate whether these preservice science teachers will be able to apply their knowledge on TPACK-P in practice of their teaching. To investigate the TPACK-P of preservice science teachers should also include lesson observations to observe how these teachers implement TPACK-P during their lessons, a further demonstration of their application of TPACK-P.

It would also be interesting to investigate the TPACK-P of practising teachers in South Africa to see whether they are on the same proficiency level of the preservice science teachers. This research can also investigate the extent to which the contextual factors inhibit or enable the use of ICTs in the classroom can also be included.

This study could be conducted at other universities in South Africa to establish the proficiency level of the preservice science teachers in the country. This will allow for a better understanding of South Africa's science preservice teachers knowledge on TPACK-P and this information can be used to inform possible revisions to their teacher professional development programmes.

5.6 Recommendations based on findings

The findings reveal that a small number of students that demonstrate a proficiency level of 1 and 2. It is therefore recommended that steps be taken to ensure that all students operate a high level of proficiency. Factors also need to be identified as to why these students demonstrate this lower level, while the great majority of students reflect a higher level of proficiency (level 3 or 4).

Despite the small number of students operating at levels 1 and 2, it is pleasing to note that the majority of student operate at levels 3 or 4. This suggests that the teacher education programme at the University of Johannesburg is very adequately addressing the TPACK-P of preservice teachers. It is therefore recommended that some of the student support materials being used at this university be made available to the Gauteng Department of Education for possible use in their in-service teacher upliftment programmes that address ICT integration.

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APPENDICES

Appendix A: Ethical Clearance

NHREC Registration Number REC-110613-036

UNIVERSITY OF JOHANNESBURG

ETHICS CLEARANCE

Dear A Pieters

Ethical Clearance Number: 2017-031

Assessing the technological pedagogical content knowledge-practical of final year pre-service science teachers

Ethical clearance for this study is granted subject to the following conditions:

- If there are major revisions to the research proposal based on recommendations from the Faculty Higher Degrees Committee, a new application for ethical clearance must be submitted.
- If the research question changes significantly so as to alter the nature of the study, it remains the duty of the student to submit a new application.
- It remains the student's responsibility to ensure that all ethical forms and documents related to the research are kept in a safe and secure facility and are available on demand.
- Please quote the reference number above in all future communications and documents.

The Faculty of Education Research Ethics Committee has decided to

☒ Grant ethical clearance for the proposed research.
☐ Provisionally grant ethical clearance for the proposed research
☐ Recommend revision and resubmission of the ethical clearance documents

Sincerely,

Prof Geoffrey Lautenbach
Chair: **FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE**
19 April 2017

Appendix B: Informed Consent

SECTION D: Signatures required for consent/assent

(for all participants, parents, guardians and other stakeholders)

UNIVERSITY OF JOHANNESBURG

Informed Consent/Assent Form

Project Title:
Assessing the technological pedagogical content knowledge-practical of final year pre-service science teachers

Investigator:
Annesca Elmare' Pieters

Date:
4/21/2017

Please mark the appropriate checkboxes. I hereby:

☐ Agree to be involved in the above research project as a participant.
☐ Agree to be involved in the above research project as an observer to protect the rights of:
  ☐ Children younger than 18 years of age;
  ☐ Children younger than 18 years of age that might be vulnerable*; and/or
  ☐ Children younger than 18 years of age who are part of a child-headed family.
☐ Agree that my child, ______________________ may participate in the above research project.
☐ Agree that my staff may be involved in the above research project as participants.

☐ I have read the research information sheet pertaining to this research project (or had it explained to me) and I understand the nature of the research and my role in it. I have had the opportunity to ask questions about my involvement in this study. I understand that my personal details (and any identifying data) will be kept strictly confidential. I understand that I may withdraw my consent and participation in this study at any time with no penalty.

☐ Please allow me to review the report prior to publication. I supply my details below for this purpose:
☐ Please allow me to review the report after publication. I supply my details below for this purpose:
☐ I would like to retain a copy of this signed document as proof of the contractual agreement between myself and the researcher

Name: ______________________

Phone or Cell number: ______________________

e-mail address: ______________________

Signature: ______________________

If applicable:
☐ I willingly provide my consent/assent for using audio recording of my/the participant's contributions.
☐ I willingly provide my consent/assent for using video recording of my/the participant's contributions.
☐ I willingly provide my consent/assent for the use of photographs in this study.

Signature (and date): ______________________

Signature of person taking the consent (and date): ______________________

Faculty of Education Research Ethics Committee, University of Johannesburg, Updated February 2016
Please report any instance of unethical research practice to geoffl@uj.ac.za or 011 559 3016

Appendix C: Questionnaire for Science Teachers' TPACK-P

Name:

Years teaching:

Teaching subjects:

Qualification:

Please answer all questions by drawing a circle around the letter.

Q1. How do you think your use of videos/animation in the classroom helps you to better understand your students' learning?

A. They help me learn how students feel about the use of videos /animation in instruction.
B. They help me assess students' content comprehension through dynamic presentations.
C. They help me elicit students' prior knowledge and/or misconceptions.
D. I don't believe videos /animation are useful for assessing students' individual differences.

Q2. How do you think simulations help you identify students'' learning difficulties?

A. They help me to discover students' learning difficulties when I use them to demonstrate phenomena, and then ask follow-up questions.
B. They help me to observe the difficulties students' face from their simulation manipulations.
C. I can identify students'' learning difficulties when they use simulations to learn science personally or collaboratively.
D. I don't believe simulations to be good tools for use in identifying students learning difficulties.

Q3. In what ways do you think technology integration can be useful in helping students' who have different learning styles/needs?

A. Technology integration can present difficult subject content in diverse and efficient ways for students to understand.
B. Technology integration allows students with different motivations or learning backgrounds to be independent learners.
C. Teachers can use technology integration to adaptively assess students' knowledge, and then offer instruction based on that assessment.
D. I don't believe that technology integration in class to assist students with different learning styles/needs.

Q4. Which of the following statements describes your understanding of technology-supported assessments?

A. Multimedia assessments allow for evaluations of various aspects of learning in ways that exceed limited conventional assessments.
B. Test bank CD-ROMs offer efficient technology-supported assessments.
C. Teachers can construct items that have multiple representations to be used for different evaluation purposes.
D. Conventional assessments are more efficient than technology-supported assessments in terms of student evaluation.

Q5. What are the distinctive features of technology-supported assessments, as compared to conventional assessments?

A. They offer instant feedback and preliminary score analyses.
B. They present dynamic content through multimedia.
C. They allow students to manipulate simulations and present their thinking processes.
D. There are no major differences in terms of item content; the key difference is in the interfaces they use to present information.

Q6. How do you think teachers should use technology-supported assessments to evaluate students' in science instruction?

A. Teachers can present scientific phenomena in diverse ways, which implies student learning can be evaluated from a wide range of perspectives.
B. Teachers can ask students' to complete science projects with technology and use their project as summative assessments of their learning.
C. Teachers can use online platforms to offer students' summative assessments or repeated practices; students'' learning progress can also be recorded.
D. Technology-supported assessments are not appropriate for implementation in instruction.

Q7. How can teachers learn more about subject content through the use of technology?

A. They can reference verified sources that professional websites offer (ex: research institute websites).
B. They can keep up to date from attending workshops or use online resources shared by internet-based teaching community.
C. They can learn more abstract concepts by using different technology functions (ex: multiple representations, slow motion displays).
D. Consulting professional books and magazines is a better way of acquiring content knowledge.

8. What types of subject content are suited to teaching with technology-supported instruction?

A. Units that require students'' motivation to learn.
B. Concepts that need students to learn from manipulating simulations or doing experiments.
C. Abstract concepts that are difficult to present in conventional instruction.
D. I don't believe that there is a significant difference between technology-supported and conventional instruction when it comes to subject content presentation.

9. What factors do you think influence teachers' planning and designing of their technology-supported instruction?

A. The improved visual effects of graphic designs and concept presentations.
B. The enhancement of student learning motivations and responses.
C. The increased efficiency of teacher instruction.
D. The amount of time spent in curriculum preparation (which may decrease teachers’ willingness to teach with technology).

10. What instructional objectives do you think are appropriate for technology-supported instruction?

A. To enhance instructional efficiency and improve students’’ comprehension and thinking abilities.
B. To help students’ form a better understanding of the course content and clarify key concepts.
C. To improve students’ learning motivation.
D. No special objectives need to be set for technology-supported instruction (To achieve the objectives like those teachers set for their conventional instruction).

11. How do you select the appropriate technology tools for content presentation?

A. Depend upon the availability of resources (ex: animation, images, PowerPoint).
B. Base on students’’ prior knowledge, instructional procedures, and subject concepts.
C. Depend upon how explicit technology present subject content and how helpful they guide students to think scientifically.
D. Presenting textbook content in PPT satisfies my instructional needs.

12. How do you select and use teaching strategies to assist technology-supported instruction?

A. I use a questioning strategy or ask students to draw from their impressions to help them identify key concepts.
B. I engage students’ in group collaboration to promote their comprehension.

C. I guide students to use technology tools or learn with inquiry for their self-learning.
D. Teaching with technology already accommodates my instructional needs; no other instructional strategies are required.

13. What do you think the effects might be when group collaborations are coupled with technology-supported instruction?

A. Technology can present course content for groups to discuss and present group findings/learning to the class.
B. Students' can develop a more positive attitude toward learning (ex: participation, learning motivation, concentration).
C. A technology-supported environment that accommodates students'' collaborative completion of tasks can be developed, but personal learning outcomes should also be carefully considered.
D. Group collaboration does not offer anything special to technology-supported instruction.

14. Compared with conventional instruction, why should technology-supported instruction be considered special?

A. It allows concepts to be presented more explicitly than teachers' visual or oral explanations.
B. It leaves students' excited and makes a lasting impression.
C. It helps abstract concepts and related examples to be concretely visualised in less time.
D. I don't believe that there is a difference in student learning between technology-supported instruction and conventional instruction.

15. Which of the following statements describe your opinions regarding synchronous communication tools, as they relate to asynchronous communication tools?

A. They benefit students' who are active in learning.
B. They improve teacher-student interactions in non-classroom settings.
C. They offer diverse learning opportunities and assessment methods.
D. Teachers are less willing to use them in instruction due to the high demands of technology.

16. How do you handle problems with technology-supported instruction?

A. I upload learning materials online for student learning.
B. I meet with students beyond class hours.
C. I use previously prepared teaching materials (ex: online or standalone versions).
D. I use chalk-and-talk instruction instead (I use none of the above).

17. Which of the following statements describe your opinions about applying technology to instruction management?

A. Curricula can become innovative and cross-disciplinary, when digital educational resources are meaningfully and purposefully integrated.
B. Operating systems (e.g., Microsoft) can be useful when organising teaching materials that have been collected over a long period of time.
C. Online platforms can be useful for profiling students'' collaborative learning progress and learning outcomes.
D. Current technology cannot effectively improve teachers' instructional management.

Appendix D: Indicators of proficiency level of science preservice science teachers TPACK-P

Indicators of proficiency level of science preservice science teachers TPACK-P

Proficiency level	Item indicator	
Level 4 - Reflective application	1 C	They help me elicit students prior knowledge and/or misconceptions.
	2 C	I can identify students' learning difficulties when they use simulations to learn science personally or collaboratively.
	3 C	Teachers can use technology integration to adaptively assess student's knowledge, and then offer instruction based on that assessment.
	4 C	Teachers can construct items that have multiple representations to be used for different evaluation purposes.
	5 C	They allow students to manipulate simulations and present their thinking processes.
	6 A	Teachers can present scientific phenomena in diverse ways, which implies student learning can be evaluated from a wide range of perspectives.
	7 C	They can learn more abstract concepts by using different technology functions (ex: multiple representations, slow motions display).
	8 B	Concepts that need students to learn from manipulating simulations or doing experiments.
	9 C	The increased efficiency of teacher instruction.
	10 A	To enhance instructional efficiency and improve student's comprehension and thinking abilities.
	11 B	Based on student's prior knowledge, instructional procedures, and subject concepts.

	12 C	I guide students to use technology tools or learn with inquiry for their self-learning.
	13 C	A technology-supported environment that accommodates student's collaborative completion of tasks can be developed, but personal learning outcomes should also be carefully considered.
	14 C	It helps abstract concepts and related examples to be concretely visualised in less time.
	15 C	They offer diverse learning opportunities and assessment methods.
	16 C	I use previously prepared teaching materials (ex: online or standalone versions).
	17 A	Curricula can become innovative and cross-disciplinary, when digital educational resources are meaningfully and purposefully integrated.
Level 3 – Infusive application	1 B	They help me assess students content comprehension through dynamic presentations.
	2 B	They help me to observe the difficulties students face from their simulation manipulation.
	3 A	Technology integration can present difficult subject content in diverse and efficient ways for students to understand.
	4 A	Multimedia assessments allow for evaluations of various aspects of learning in ways that exceed limited conventional assessments.
	5 B	They present dynamic content through multimedia.
	6 C	Teachers can use online platforms to offer students summative assessments or repeated practices: students learning progress can also be recorded.
	7 A	They can reference verified sources that professional websites offer (ex: research institute websites).

	8 C	Abstract concepts that are difficult to present in conventional instruction.
	9 A	The improved visual effects of graphic designs and concept presentations.
	10 B	To help students form a better understanding of the course content and clarify key concepts.
	11 C	Depend upon how explicit technology presented subject content and how helpful they guide students to think scientifically.
	12 B	I engage students in group collaboration to promote their comprehension.
	13 A	Technology can present course content for groups to discuss and present group findings/ learning to the class.
	14 A	It allows concepts to be presented more explicitly than teachers' visual or oral explanations.
	15 B	They improve teacher-student interactions in non-classroom settings.
	16 A	I upload learning materials online for student learning.
	17 C	Online platforms can be useful for profiling students collaborative learning progress and learning outcomes.
Level 2 – Simple adopting	1 A	They help me to learn how students feel about the use of videos/ animation in instruction.
	2 A	They help me to discover students learning difficulties when I use them to demonstrate phenomena, and then ask follow-up questions.
	3 B	Technology integration allows students with different motivations or learning backgrounds to be independent learners.
	4 B	Test bank CD-ROMs offer efficient technology-supported assessments.

	5 A They offer instant feedback and preliminary score analyses. 6 B Teachers can ask students to complete science projects as summative assessments of their learning. 7 B They can keep up to date from attending workshops or use online resources shared by internet-based teaching community. 8 A Units that require student's motivation to learn. 9 B The enhancement of student learning motivations and responses. 10 C To improve students learning motivation. 11 A Depend upon the availability of resources (ex: animation, images, PowerPoint). 12 A I use a questioning strategy or ask students to draw from their impressions to help them identify key concepts. 13 B Students can develop a more positive attitude towards learning (ex: participation, learning motivation, concentration). 14 B It leaves students excited and makes a lasting impression. 15 A They benefit students who are active in learning. I meet with students beyond class hours. 16 B Operating systems (e.g., Microsoft) can be useful when organising teaching materials that have been 17 B collected over a long period of time.
Level 1 – Lack of use	1 D I don't believe videos/ animation are useful for assessing students' individual differences. 2 D I don't believe simulations to be good tools for use in identifying students learning difficulties.

	3 D I don’t believe that technology integration in class to assist students with different learning styles/needs. 4 D Conventional assessments are more efficient than technology-supported assessments in terms of student evaluation. 5 D There are no major differences in terms of item content; the key difference is in the interfaces they use to present information. 6 D Technology-supported assessments are not appropriate for implementation in instruction. 7 D Consulting professional books and magazines is a better way of acquiring content knowledge. 8 D I don’t believe that there is a significant difference between technology-supported and conventional instruction when it comes to subject content presentation. 9 D The amount of time spent in curriculum preparation (which may decrease teachers’ willingness to teach with technology). 10 D No special objectives need to be set for technology-supported instruction (To achieve the objectives like those teachers set for their conventional instruction). 11 D Presenting textbook content in PPT satisfies my instructional needs. 12 D Teaching with technology already accommodates my instructional needs; no other instructional strategies are required. 13 D Group collaboration does not offer anything special to technology-supported instruction.

	14 D I don’t believe that there is a difference in student learning between technology-supported instruction and conventional instruction. 15 D Teachers are less willing to use them in instruction due to high demands of technology. 16 D I use chalk-and-talk instruction instead (I use none of the above). 17 D Current technology cannot effectively improve teachers’ instructional management.

Appendix E: Persons weighted likelihood ability estimates

Table 6: Persons Weighted likelihood ability estimates

pid	N.items	PersonScores	PersonMax	WLE	error	WLE.rel
1	17	14	68	-1,93574	0,273538	0,509806
2	17	42	68	-0,48406	0,233133	0,509806
3	17	50	68	-0,00367	0,261445	0,509806
4	17	51	68	0,065364	0,266391	0,509806
5	17	43	68	-0,42964	0,235806	0,509806
6	17	49	68	-0,0703	0,256898	0,509806
7	17	49	68	-0,0703	0,256898	0,509806
8	17	50	68	-0,00367	0,261445	0,509806
9	17	52	68	0,137049	0,271805	0,509806
10	17	52	68	0,137049	0,271805	0,509806
11	17	49	68	-0,0703	0,256898	0,509806
12	17	40	68	-0,58928	0,228443	0,509806
13	17	45	68	-0,31659	0,241823	0,509806
14	17	46	68	-0,25774	0,245186	0,509806
15	17	46	68	-0,25774	0,245186	0,509806
16	17	47	68	-0,19717	0,248804	0,509806

17	17	47	68	-0,19717	0,248804	0,509806
18	17	49	68	-0,0703	0,256898	0,509806
19	17	49	68	-0,0703	0,256898	0,509806
20	17	49	68	-0,0703	0,256898	0,509806
21	17	50	68	-0,00367	0,261445	0,509806
22	17	50	68	-0,00367	0,261445	0,509806
23	17	52	68	0,137049	0,271805	0,509806
24	17	40	68	-0,58928	0,228443	0,509806
25	17	42	68	-0,48406	0,233133	0,509806
26	17	44	68	-0,37385	0,2387	0,509806
27	17	45	68	-0,31659	0,241823	0,509806
28	17	46	68	-0,25774	0,245186	0,509806
29	17	46	68	-0,25774	0,245186	0,509806
30	17	47	68	-0,19717	0,248804	0,509806
31	17	49	68	-0,0703	0,256898	0,509806
32	17	50	68	-0,00367	0,261445	0,509806
33	17	40	68	-0,58928	0,228443	0,509806
34	17	43	68	-0,42964	0,235806	0,509806
35	17	46	68	-0,25774	0,245186	0,509806

36	17	46	68	-0,25774	0,245186	0,509806
37	17	48	68	-0,13474	0,252698	0,509806
38	17	48	68	-0,13474	0,252698	0,509806
39	17	52	68	0,137049	0,271805	0,509806
40	17	47	68	-0,19717	0,248804	0,509806
41	17	47	68	-0,19717	0,248804	0,509806
42	17	48	68	-0,13474	0,252698	0,509806
43	17	49	68	-0,0703	0,256898	0,509806
44	17	51	68	0,065364	0,266391	0,509806
45	17	46	68	-0,25774	0,245186	0,509806
46	17	47	68	-0,19717	0,248804	0,509806
47	17	42	68	-0,48406	0,233133	0,509806
48	17	49	68	-0,0703	0,256898	0,509806
49	17	44	68	-0,37385	0,2387	0,509806
50	17	50	68	-0,00367	0,261445	0,509806
51	17	50	68	-0,00367	0,261445	0,509806
52	17	54	68	0,289684	0,284418	0,509806
53	17	59	68	0,752292	0,334645	0,509806
54	17	48	68	-0,13474	0,252698	0,509806

55	17	46	68	-0,25774	0,245186	0,509806
56	17	47	68	-0,19717	0,248804	0,509806
57	17	50	68	-0,00367	0,261445	0,509806
58	17	51	68	0,065364	0,266391	0,509806
59	17	51	68	0,065364	0,266391	0,509806
60	17	51	68	0,065364	0,266391	0,509806
61	17	51	68	0,065364	0,266391	0,509806
62	17	51	68	0,065364	0,266391	0,509806
63	17	52	68	0,137049	0,271805	0,509806
64	17	53	68	0,211695	0,277776	0,509806
65	17	53	68	0,211695	0,277776	0,509806
66	17	54	68	0,289684	0,284418	0,509806
67	17	55	68	0,371496	0,291876	0,509806
68	17	55	68	0,371496	0,291876	0,509806
69	17	55	68	0,371496	0,291876	0,509806
70	17	56	68	0,457744	0,300339	0,509806
71	17	57	68	0,549215	0,310051	0,509806
72	17	60	68	0,867135	0,350588	0,509806
73	17	47	68	-0,19717	0,248804	0,509806

74	17	47	68	-0,19717	0,248804	0,509806
75	17	50	68	-0,00367	0,261445	0,509806
76	17	50	68	-0,00367	0,261445	0,509806
77	17	51	68	0,065364	0,266391	0,509806
78	17	51	68	0,065364	0,266391	0,509806
79	17	52	68	0,137049	0,271805	0,509806
80	17	53	68	0,211695	0,277776	0,509806
81	17	53	68	0,211695	0,277776	0,509806
82	17	53	68	0,211695	0,277776	0,509806
83	17	53	68	0,211695	0,277776	0,509806
84	17	54	68	0,289684	0,284418	0,509806
85	17	55	68	0,371496	0,291876	0,509806
86	17	55	68	0,371496	0,291876	0,509806
87	17	62	68	1,136937	0,394423	0,509806
88	17	48	68	-0,13474	0,252698	0,509806
89	17	46	68	-0,25774	0,245186	0,509806
90	17	47	68	-0,19717	0,248804	0,509806
91	17	49	68	-0,0703	0,256898	0,509806
92	17	52	68	0,137049	0,271805	0,509806

93	17	53	68	0,211695	0,277776	0,509806
94	17	53	68	0,211695	0,277776	0,509806
95	17	54	68	0,289684	0,284418	0,509806
96	17	56	68	0,457744	0,300339	0,509806
97	17	58	68	0,646941	0,321339	0,509806
98	17	58	68	0,646941	0,321339	0,509806
99	17	59	68	0,752292	0,334645	0,509806
100	17	59	68	0,752292	0,334645	0,509806
101	17	53	68	0,211695	0,277776	0,509806
102	17	57	68	0,549215	0,310051	0,509806
103	17	58	68	0,646941	0,321339	0,509806